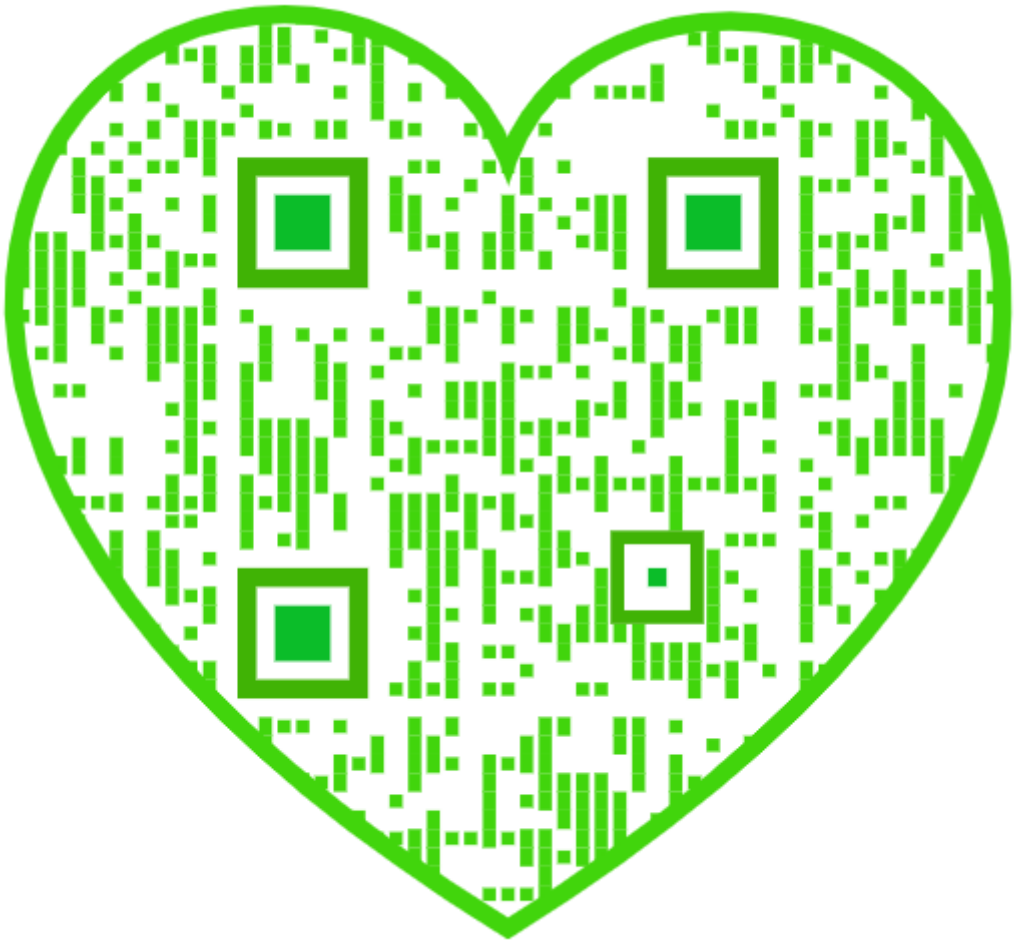

THE NEW AIR WORLD

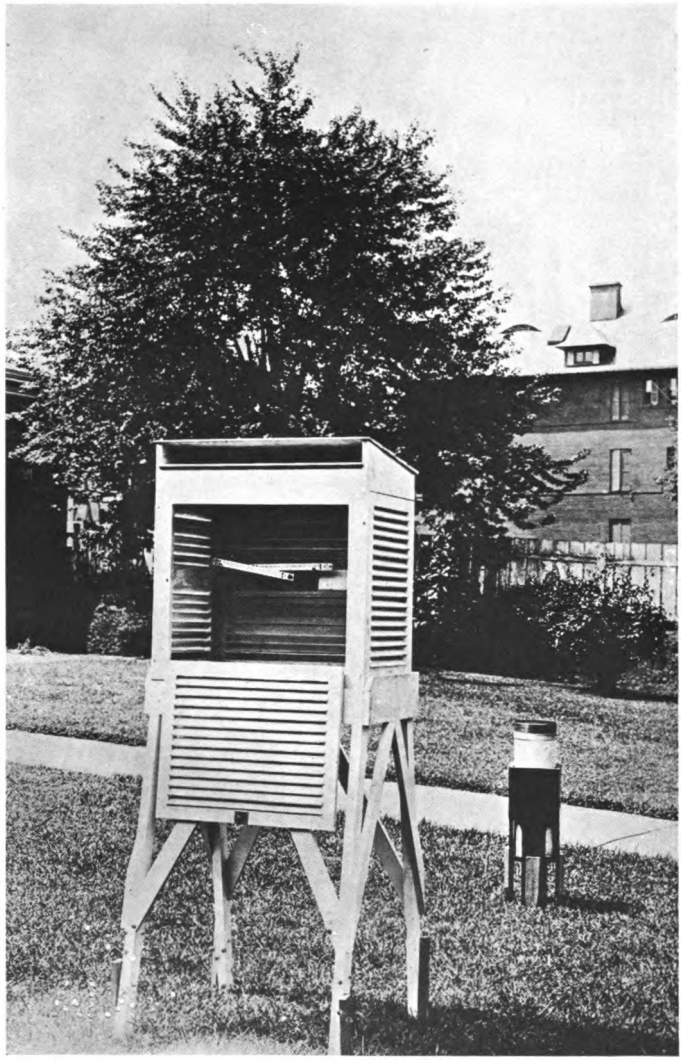

FIG. 4. — INSTRUMENT SHELTER. Frontispiece.
(*Page 66*)

THE NEW AIR WORLD

The Science of Meteorology Simplified

BY

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AFFECTIONATELY DEDICATED

TO

A FRIEND OF MANY AND PLEASANT YEARS

A BELOVED TEACHER AND A

GREAT CHEMIST

DR. CHARLES E. MUNROE, PH.D.

609659

INTRODUCTION

THE author's "Descriptive Meteorology" (Appleton, 1914) is designed for the teaching of those who intend to make Meteorology a profession. This book is planned for the reading of those who desire to know something of the wonders of the New Air World into which man is just now entering, for those who desire to become weatherwise and make forecasts for themselves, and to apply their knowledge to their business, their health, and their happiness; and for the reading of the more advanced pupils of the public schools.

So far as possible technical terms are avoided and an effort made to tell a simple story that will awaken curiosity and lead the reader to wish to know more and more of the mysteries of the atmosphere, of which practically nothing was known at the time of the landing of the Pilgrims, Torricelli not having discovered the barometer until twenty-three

years later. It will be made plain how atmospheric air was formed, how long it will remain, whither it will go, how it is heated, cooled, and lighted; where and how storms, cold waves, clouds, frosts, and fair-weather conditions originate and how move; how the cyclone, the tornado, and the thunderstorm may be recognized on the Daily Weather Map of the Government and their future activities forecast; how a fund of simple yet wonderful information that will be of inestimable value may be acquired by any intelligent person.

The author acknowledges courtesies extended to him by Prof. Charles F. Marvin, present chief of the Weather Bureau, and by R. H. Weightman, chief clerk of the Bureau, in the matter of securing several important illustrations; and like favors extended to him by D. Appleton and Company, John Wiley & Sons, and the Taylor Instrument Company, of Rochester, N. Y.

W. L. M.

AUGUST, 1922

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THE NEW AIR WORLD

CHAPTER I

ATMOSPHERES OF THE EARTH, THE SUN, AND THE PLANETS

How Atmospheres Are Formed. Once there were no such things on the earth as hills and mountains, singing brooks, roaring rivers and vast oceans; and the delicately hued landscape, with its winding roads, hedges, flowers, green fields, and golden grain, had not evolved from the atmosphere. The earth had not yet cooled down to the condition of a solid crust, everything that the eye now sees existed in the form of invisible gases, or as clouds incandescent with white heat. Fiery blasts swirled over the face of the earth. Storms a million times more powerful than the most destructive West Indian hurricane of the present day moved through the indescribably hot atmosphere, throwing down not rain as we under-

stand it, but liquid earth and metal, as their rising clouds ascended and cooled. It is difficult for the human mind to grasp the wonders of this.

Small planets cool quicker than large ones and sooner come to the conditions of a crust and to a temperature suitable for the development of the various forms of life.

Atmosphere of the Sun. To the unaided eye it appears as a smooth, bright, quiescent sphere, but the telescope reveals millions of agitations and hundreds of red flames that shoot outward to distances of hundreds of thousands of miles. One can form no adequate picture of the convulsions of the atmosphere of the sun. During eclipses, when the intense glare of its center is obscured, hydrogen flames may be seen darting outward for as much as a million miles.

Lifeless Planets. The larger a planet the longer is the time that must elapse before the hot vapors of rock and metal, which largely compose its early atmosphere, cool and congeal into a crust, leaving as a residual an atmosphere of such heat, density, and composition as to permit of the beginnings of the forms of life that have inhabited the world. Before the sun can reach this condition, an indescribable period will have elapsed, its light will have gone out,

its heat will have ceased to reach the earth and the other planets in quantities sufficient to maintain life, the earth will have been dead millions of years, and the sun itself will only receive heat and light from the feeble rays of the stars that, unlike itself, have not yet ceased to shine. But even then the sun ever must remain dead, for there is no external source whence it may receive heat. No vegetation can adorn it, no water flow upon its surface, neither can the foot of any man press its soil.

Jupiter, and perhaps Neptune, Uranus, and Saturn, have hot atmospheres still in violent agitation, — molten surfaces composed of all kinds of matter, from which bubble and boil off hot clouds of vapor that surge about in huge eddies or cyclonic storms, and that here and there are shot outward in tongues of fire. The earth millions of years ago had a similar atmosphere. But when the heat energy of these vaporous planets wanes, and they cool down, as the earth did many years ago, the simplest forms of life cannot be evolved upon them, for they are too far away from the sun to receive life-giving heat. Mars receives less than half the intensity of the solar rays that come to the earth, Jupiter only 0.037, Saturn 0.011, Uranus 0.003, and Neptune 0.001.

In due time — some hundreds of millions of years

— the cooling of the sun will leave the earth to freeze and all life to become extinct, unless, perchance, the oxygen of the air is so far absorbed by its rocks, or filtered away into space, as to destroy life before that time. No matter what may be the achievements of the human mind, what wonderful civilizations may be developed, what powerful empires created, or what wonderful secrets of creation discovered, it seems certain that these all will pass away, and finally the surface of the earth be as if man never lived. The dust of ages will wipe out and obliterate every trace and vestige of the operations of life. Silence, cold, and darkness will then reign supreme. But the time of this is indescribably far off in the future, and man will have ample opportunity to develop to the highest mental and spiritual estates of which he has inherent possibilities.

The moon already is dead. If it is formed of matter abandoned by the earth, as we believe, it once must have had an atmosphere, a portion of which was absorbed by its rocks as it cooled, and the remainder lost as the result of the low power of attraction of so small a body, which is insufficient to prevent the darting molecules of the gases of its air from shooting off into space. The absence of an atmospheric covering allows the heat from the sun to

escape almost as rapidly as it is received; and the long nights of the moon (each as long as fourteen of our days) during which the sun's rays are entirely cut off, permit the temperature of the dark side to fall to something like −400° F.

How Atmospheres Are Maintained and How Lost. The processes of nature are always adding to the various gases of the atmosphere in some ways, and transforming or taking from them in other ways. On the earth the loss and the gain are so nearly equal as to maintain at present a nearly constant condition. Marked changes have taken place, however, in long geologic periods. Our early atmosphere probably contained large quantities of carbon dioxide which were absorbed by the rank vegetable growth that now forms the coal beds of the earth, and the slowly cooling rocks that constitute the crust took in large quantities of oxygen; in fact, nearly one half of the weight of the crust of the earth is composed of the latter element.

In consequence it may be said that our present atmosphere is what remained after the earth had absorbed its gases nearly to depletion, and after the lighter gases, like hydrogen and helium, which seem to have too great molecular velocity to be imprisoned by the earth's attraction of gravitation,

had been lost in space. Gases that cannot be held by the moon may be imprisoned by the earth and those that can escape from the earth may be held by the larger planets.

Height of the Earth's Atmosphere. Exact computation has shown that if the air were the same density at all elevations, which it is not, it would extend upward a distance of only five miles. From laws that are well understood it is known that at a height of thirty miles the atmosphere is only about one hundredth as dense as it is at the surface of the earth, and that at fifty miles it is too light to manifest a measurable pressure. The oxygen ceases at about thirty miles and the nitrogen at about fifty miles, the water vapor being restricted below the five-mile level. The appearance of meteors, which are rendered luminous by rushing into the earth's atmosphere, and whose altitudes have been determined by simultaneous observations at several stations, reveals the presence of hydrogen and helium at a height of nearly two hundred miles.

CHAPTER II

A SYNOPTIC PICTURE OF THE AIR

How much do you know of the great aërial ocean on the bottom of which you live and in which human beings are just beginning to fly? Its variations of heat, cold, sunshine, cloud, and tempest materially affect not only the health and happiness of man but his commercial and industrial welfare, and yet few know more than little of the wonders of the life-giving medium that so intimately concerns them.

At the Height of Two Hundred Miles. Here is only the invisible, the intangible ether which, while too tenuous to be detected or measured by any appliances of man, is supposed to transmit the rays of the sun. These rays, coming in the form of many different wave lengths, and with widely differing velocities of vibration, produce a multitude of phenomena as they are absorbed by or pass through the air, or as they reach the surface of the earth.

The longer and slower waves are converted into heat, the shorter and more rapid ones into light, and the minutest movements probably into electricity.

Oxygen and nitrogen, which form the greater part of the atmospheric gases, absorb comparatively little of the solar rays, while water vapor, which constitutes a little more than one per cent. of the atmosphere and which remains close to the earth, absorbs large quantities. From the fact that one half of the atmosphere, including nearly all of its water vapor, lies below an elevation of three and one half miles, it becomes evident that the greater part of the absorption of the sun's rays must take place in the lower strata. On clear days the atmosphere absorbs nearly one half of the sun's heat rays; the remainder reaches the surface of the earth, warms it and in turn is radiated back into the air, — with this difference: that as earth radiation the wave motion of the rays is longer and slower than it was when the rays entered our atmosphere as solar radiation. In this slower form the rays are the more readily absorbed. The atmosphere is thus warmed largely from the bottom upwards, which accounts for the perpetual freezing temperatures of high mountain peaks, although they are nearer the sun than are the bases from which they rise.

At the Height of One Hundred Miles. The temperature at this altitude must be that of outside space, probably 459° F.[1] below zero. Air liquefies at 312° below, and therefore it cannot exist in the gaseous state in a region having a lower temperature. When it liquefies it has the color and general appearance of water, and about the same specific gravity.

When a piece of steel and a lighted taper are brought together inside of a vessel filled with liquid air, the dense supply of oxygen makes combustion so rapid that the hard metal burns like tinder.

At the Height of Fifty Miles. There is enough air here to refract light slightly, as at twilight, and to render luminous the meteors that rush with fearful velocity against its widely scattered molecules. At this distance from the earth there probably is no more air than would be found under the receiver of the best air pump, and, the reader will be surprised to learn, darkness is practically complete, although the hour may be midday, for there are no dust motes to scatter and diffuse and render visible the light rays of the sun. (See Chapter III.)

The Darkness of Outer Space. It may be proven by taking an inclosed volume of air, freeing it of

[1] Unless otherwise expressed in this book it will be understood that all temperatures are recorded by the Fahrenheit scale.

dust motes, of which there are millions per cubic centimeter, and then trying to illuminate it; it will be found that no matter how powerful the light directed into it, it remains wholly dark. When one looks upward on a clear day, he apparently sees the whole universe illuminated; but in point of fact only the thin stratum of the earth's air in which he lives is illuminated. Outer space is practically without temperature or light. The rays of the sun do not become either light or heat or electricity until they encounter the molecules of the air, or the invisible dust motes, or the cloud particles near the earth and through interference are transmuted from etheric vibrations into other forms of energy.

The Bacteria of Disease and of Putrefaction. These rapidly diminish in number with elevation, and on the tops of the highest mountain peaks practically none are found. Mid-ocean also shows but few.

At the Height of Twenty-five Miles. Air, light as it is, has still sufficient density to obstruct the passage of the minutest wave lengths of light, and here probably begins to be appreciable the blue tint of the heavenly vault. At this short distance from the earth there must be a deathlike stillness, for there is no medium sufficiently dense to transmit

sound. Two persons could not hear each other speak, even if they could live in this rare atmosphere, which they could not. Here is eternal peace and no apparent motion, for storms and ascending and descending currents cease long before this level is reached. The cold is intense and daylight but a feeble illumination. There are no clouds.

Isothermal Stratum Entered at the Height of Seven Miles. We know that the temperature decreases rapidly with ascent — about one degree for each three hundred feet — until the top of the storm level is reached, at about seven miles, when a most wonderful discovery is made: the thermometer no longer falls as the aviator rises, or as balloons float to great altitudes carrying self-registering instruments. The temperature remains practically stationary, so far as exploration has been made, which is to the height of over nineteen miles. Major R. W. Schroeder, U. S. A., flew in an aëroplane to 36,000 feet and recorded a temperature of 69° below zero.

We have named this region above storms the *Isothermal* stratum. (See Figure 1.) Its temperature everywhere is about 70° below zero and it changes only about six degrees between winter and summer. Of course we must assume that ultimately the

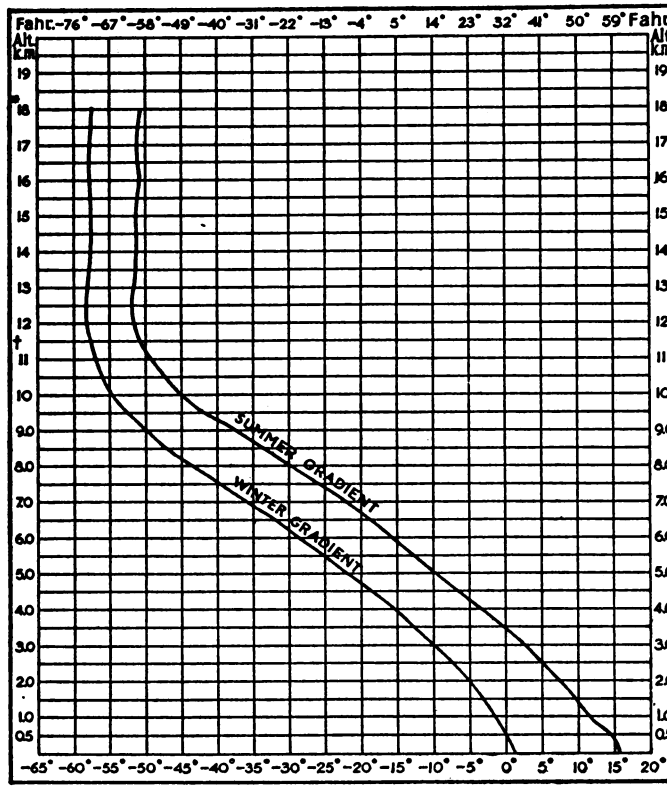


FIG. 1. — Winter and Summer Vertical Temperature Gradients, in degrees Centigrade and Fahrenheit.

temperature shades away to practically nothing as outer space is reached.

Scientific and inventive genius is becoming so skillful in harnessing the forces of nature to man's desires that it is reasonable to anticipate that within a quarter of a century or less human beings will be

nearly as numerous in the air as insects, they will remain aloft longer, and sail to vastly greater distances and to higher altitudes. In time dirigible ships may sail for days and possibly for weeks in the pure air aloft, carrying millions of passengers.

At a Height of One and One Half Miles. There is little difference in the temperatures of day and night, except that the coolest time of the twenty-four hours is during daytime and not at night, as would be most naturally supposed. This is important inform ion to an aviator or to the pilot of a balloon.

At an Altitude of One Thousand Feet. In free air at the hottest time in midsummer's heat, the air is found to be as much as fifteen degrees lower than that at the ground. Almost within arm's length of the streets of great inland cities there is a cool and healthful atmosphere when humanity is sweltering and dying from heat below. Some youth who is reading this may develop the genius that will lift up whole city blocks into this cool and healthful region. Open steel work below, the first level at one or two thousand feet above the hot streets, express elevators to carry passengers, and the climate of the cool mountain air is accessible to those who now live in discomfort at low populous centers.

Man is just beginning to disport himself in the hitherto trackless wilderness of the air. Certain it is that the hanging gardens of Babylon will be outdone in the Twentieth Century and the eyrie of the eagle left far below by those who will live a part of their time in elevated structures having bases resting upon the earth; or who will fly to great distances aloft and remain at whatever altitude furnishes them the most pleasant and beneficial conditions, and that they may thus remain not only for days but for weeks without returning to the surface of the earth.

Only during recent years have we realized how thin is the stratum of air next to the earth which has sufficient heat and moisture for the inception, growth, and maturity of animal and vegetable life. The raising of the instrument shelter at the New York station of the U. S. Weather Bureau from an elevation of one hundred and fifty feet above the street to an altitude of three hundred feet has caused an apparent lowering of the mean annual temperature of two and one half degrees.

Air is so elastic and its density diminishes so rapidly with elevation that nearly one half of the weight of the entire mass of the atmosphere lies below the level of the top of Pike's Peak, which has a

height of a little less than three miles above sea level. It presses with a weight of about fifteen pounds per square inch of surface, and its pressure is exerted in all directions, upward as well as downward. An ordinary man sustains a pressure of over one ton on each square foot of his surface, but as the air penetrates all portions of his body and exercises a pressure outward as well as inward he feels no inconvenience. If his body could be so tightly sealed that no air could enter and if then the air of the interior should be removed with a pump, his body instantly would be crushed to a shapeless pulp.

A cubic foot of atmospheric air weighs one and one third ounces. Water is 773 times, and mercury ten thousand times, as dense as air. But air is a more ponderable substance than many suppose; an ordinary lecture hall forty by fifty feet and thirty feet from floor to ceiling contains two and one half tons of air at freezing temperature. It would contain less at a higher temperature, because heat expands its volume; it would contain more at a lower temperature, because cold contracts its volume.

Everything Evolved from the Air. Air is so common that we seldom stop to consider the magnitude of the force it exerts or the grandeur wrought by

this invisible architect of nature. In the great cycle of world building — birth from the nebulæ, growth, maturity, decay, disintegration, death, and then possibly back again to the nebulæ — the atmosphere, be it light and tenuous as at present, or be it filled with the hot vapors of earth and metal, is the vehicle and the medium of the builder, transporting and transmuting, in mysterious ways and to wondrous forms, the materials of planets. Its work as a builder may be further illustrated by showing that the body of man itself returns not to the earth earthy, as we have been taught, but largely to the air whence it came. Decomposition is but the liberation of the aëriform gases of which it is mainly composed; the residue is but a handful that goes back to mother earth. Let us take the dried corn plant; weigh it, then burn it in a closed vessel so that none of the ashes can blow away. Continue the burning until the ashes are perfectly white and it will be found that the weight of the ashes is only about one twentieth of the weight of the great stalk, ear, and foliage we began with. What has become of all the rest? The fire has destroyed it, you say. No, we can destroy nothing. Remember that; we can destroy nothing that the Creator has made, neither matter nor force. The fire has simply

changed the form of the plant; the nineteen twentieths that have disappeared have gone back to the air whence they came.

Thus we see that the body of man, the cereal and fruit that furnish him food, the structure that gives him shelter, aye, the many things that please the eye: the landscape, the beautiful flowers, the green fields, the babbling brooks, even the rose blush on the maiden's cheek,[1] — really come from this wonderful fluid surrounding the earth, and well may it be said that the queen of life rides upon the crest of the wind.

[1] The author wishes that this were literally true, for he believes that no great man or great woman ever was born from a mother with a painted face, dyed lips, false hair, and a body pitifully distorted by ungracefully ambling about in high heeled shoes. The power of suggestion is so great in its influence on the plastic mind of youth that a mother who is little else than a perambulating falsehood will leave descendants wanting in many if not all of the attributes of manly and womanly virtues.

CHAPTER III

EXPLORATION OF THE ATMOSPHERE

DISCOVERIES AS VALUABLE TO THE FUTURE AS THOSE MADE BY COLUMBUS

An entire new world is coming within the range of man's vision. Its possibilities for adding to the health and happiness of mankind are almost limitless. The geographic poles have been conquered and the jungles of Africa traversed; and deep borings have been made into the bowels of the earth until heat has arrested further progress. The further exploration of both regions is of the utmost importance to the coming age. It is not at all visionary to assume that the heat of the earth's interior in near time will furnish the power necessary to do the drudgery of mankind, give warmth and light to habitations, and operate transportation systems; and the New World Above offers pure, electrified,

and highly stimulating air into which helium-inflated dirigible balloons will sail, and in which they will remain not only days but weeks or longer, with their multitudes of people.

While the use of kites and balloons in sending automatic meteorological instruments far aloft has revealed more of the wonders of this hitherto uncharted wilderness of cold and partial or total darkness than the general public is aware of, only the outer fringes of the mysterious regions above the clouds and the storms have been penetrated.

When the manufacture of helium, a noncombustible gas almost as light as hydrogen, becomes more general, as seems imminent in the United States, the dirigible balloon may successfully compete with the railroads in the carrying of long-distance passengers. The recent loss of over forty lives in England by the collapse of the dirigible ZR2 probably was largely if not entirely due to the explosion and fire of the hydrogen gas with which the ship was inflated.

A decade ago, in a number of Chautauqua lectures, the writer invariably was greeted with looks of incredulity when he prophesied that within ten years travelers of the air would take breakfast at the Waldorf-Astoria in New York and afternoon tea

on the banks of the Thames. And yet the ocean already has been crossed by an aëroplane in continuous flight, and in the near future it is highly probable that aërial navigation will be safer than travel by rail or automobile. The hitherto inaccessible parts of the earth will be sailed over and closely scrutinized, while travelers enjoy the comforts that heretofore have been associated with Pullman service.

In 1862 the English meteorologist Glashier ascended in a balloon to about the same height as that attained by Major R. W. Schroeder, U. S. A., who achieved a more difficult feat when he flew in an aëroplane to over 36,000 feet. And at Dayton, Ohio, celebrated as the home of the Wright brothers, on September 28, 1921, Lieutenant John A. Macready, U. S. A., reached the unprecedented height of 40,800 feet. These are the extreme altitudes to which human beings ever have attained, but they are only the beginning of explorations into a vast and largely unknown and extremely cold region, — one in which darkness increases with elevation until at the outer limits of the atmosphere no illumination whatever exists.

The high eastward wind and 69° below zero encountered by Schroeder are conditions that already

had been revealed by the work done at the research station of the Weather Bureau, at Mount Weather, Virginia, and at other stations in this country and in Europe, by the sending up of instruments unaccompanied by observers. Under the direction of the writer the Weather Bureau liberated numerous small hydrogen gas balloons in the Rocky Mountain region, to which were attached automatic instruments registering the temperature, pressure, and the hygrometric conditions. As they came eastward in the atmospheric drift that always prevails above the storms in the middle latitudes they attained to great altitudes, one balloon reaching 19.1 miles, the greatest altitude ever reached at that time by the appliances of man. Ultimately the balloons would explode as they expanded under the influence of decreasing air pressure and the case of instruments would descend slowly under a parachute designed to open at the right moment. The barometer traced a line on a paper cylinder revolving by clock works, as did the thermometer. The thermogram gave the temperature that corresponded with the varying elevation shown by the tracing of the barogram.

In 1898, twelve hundred observations were made with kites by the observers of the Weather Bureau

at seventeen stations selected by the writer, during the six warm months from May to October. It was surprising to find the temperature often losing as much as fifteen degrees with the first thousand feet ascent during middays of extremely hot periods. The average decrease in temperature per thousand feet elevation for all stations for all times, and at all elevations up to 5280, was 4°.

For over five years kites were used nearly every day in the year at Mount Weather to carry instruments aloft to heights ranging from two to four and one half miles, and at times to keep the apparatus up during all hours of the day, so that a comparison could be made of the difference between day and night temperatures. There is but little difference between midday and midnight at only a few thousand feet above the earth.

Few are aware that the rectangular kite of the weather man was the forerunner of the aëroplane of the aviator. In 1903, while directing wireless experiments in the sending of messages at Roanoke Island, North Carolina, the writer saw the Wright brothers, or their representatives, lying flat upon the lower planes of what appeared to be Weather Bureau kites and gliding in the air from the top of the sand dunes. This was the beginning of real

flight by man. The ingenuity of the Wrights transformed the weather man's kite, strengthened it, took out the ends, hitched on a rudder, and when the petrol engine had developed sufficient power with a given weight, installed it, and flew.

In the future the meteorologist and the aviator will be closely associated. With a sufficient number of weather observations made by aviators simultaneously and well distributed over the United States it will be possible to construct a daily weather map on some high level — say the three-mile level — similar to the map now based upon sea level. The pressure, temperature, wind direction, clouds, and rainfall would be recorded and charted for the upper region clear across the continent. Three miles is about halfway to the top of cyclonic storms and probably in the region of greatest activity. More accurate forecasts would be possible by the study of this additional weather chart. This co-operation of the bird man and the weather man in studying the geography of the new air world will mark an epoch in meteorological science as far-reaching in its consequences as were the discovery of the barometer by Torricelli and the uncovering of the principles of the thermometer by Galileo, the former of which was not known until more than

twenty-three years after the landing of the Pilgrims at Plymouth Rock. Thus swiftly does the mind of man to-day explore the hidden recesses of nature's mysteries, and with each conquest carry itself to a higher realm of existence.

In the not distant future, more storm warnings may be issued by the Weather Bureau for ships of the air than for those of the sea, for the navigation of the air must play an increasing and important part in the coming activities of the world. Science is becoming so skilled in the harnessing of the forces of nature to man's desires and in the development of mechanical appliances, that it is reasonable to anticipate the possibility that long-distance travel over land or ocean ultimately will be almost entirely confined to the air.

As the result of the explorations of the atmosphere made by the institution at Mount Weather there was ready for our fighting air men at the front, immediately on our entry into the World War, a fund of useful information concerning a region that but a short time before was entirely uncharted. The instruments carried by the exploring kites and balloons had keen scientific eyes and they recorded on clock-timed cylinders what they saw. Thus did the air pilot know much about the direction and

the force of the wind that he would encounter as he rose, the altitude where he would pass above clouds, the degree of cold that he would encounter, etc. He was told that the temperature would fall about one degree for each three hundred feet of his ascent until he reached the top of the storm stratum at six or seven miles, and that if he could reach that altitude he would observe a most wonderful phenomenon: the temperature no longer would fall with gain in altitude; he would enter a cold but an equally heated stratum, without finding any temperatures lower than were encountered upon entering the region, which is always about seventy degrees below zero.

If the aërial explorer could stop his ship and keep it at an altitude of about one and one half miles for twenty-four hours he would be startled to find that the coolest time of the period was during the day-time, not during the night, as he had expected to find it.

In the future the traveler in the upper reaches of the atmosphere will carry oxygen and make the kind of air that he wishes to breathe, and he will properly protect himself against the cold of his new world, which he will find deficient in dust motes and doubtless entirely wanting in the bacteria of putrefaction and of disease. There will be no clouds to

obscure his vision; no rain or snow. He will not often ascend above the region where there are not some dust motes to scatter and diffuse a part of the solar rays and give him at least a partial illumination.

Few persons are familiar with the simple problems of the air which have such important bearing on the distribution of man into realms above those he has been accustomed to occupy. They do not know that the northwest wind brings physical energy and mental buoyancy because it has a downward component of motion that draws air from above, where it is free of impurities, and where high electrification has changed a considerable quantity of its oxygen into ozone, in which condition it remains but a short time after reaching the lower potential near the earth's surface. More people die under the influence of the south wind than under the influence of the north wind, because the south winds hug the surface of the earth and become laden with impurities and are lacking in electrical stimulation. When inventive man becomes more familiar with the ocean on the bottom of which he has heretofore lived, he will not wait for the north wind to bring down to him the beneficial conditions that always exist higher up; he will go after them and remain aloft as long as he desires to do so.

The further development of the dirigible balloon and the aëroplane are among the most important duties that the engineer of the future owes to civilization; and the meteorologist must establish the climatology of the vast untracked regions above the highest mountain peaks, for here man will largely disport himself in the time to come.

The writer agrees with the opinion of Major William R. Blair, formerly of his staff when he was the head of the U. S. Weather Bureau, but since the beginning of the World War the chief meteorological assistant of the Chief Signal Officer of the U. S. Army when he says:

"With reference to air travel in the future: the present stage of aircraft development seems to indicate that long non-stop traffic, both freight and passenger, in the air will be by means of lighter-than-air craft (balloons). These craft have much larger carrying capacity than any airplanes now designed and will travel across the continent over several prepared routes, stopping only at important centers on these routes to discharge and take up passengers and freight. It is believed that airplanes (heavier-than-air craft) will ply between these important centers and the outlying country about them, thus acting as feeders to the main route, over which the monstrous dirigibles will operate. Most transoceanic as well as transcontinental air

traffic will probably be carried on in these large dirigible balloons."

Lieutenant Colonel Henry B. Hersey, who served through the World War in the Aëronautical Service of the Signal Corps, U. S. A., and who also was associated with the writer in the management of the Weather Bureau, says:

"The fields of the dirigible and the air plane are separate and there is no conflict between the two. For light loads, great speed, and quick manœuvering, the airplane is supreme. For heavy loads, long distance, ability to remain in the air for great periods of time, the dirigible is the only air craft that can fulfill the requirements. Dirigibles will soon be in use which can start from Europe, sail over New York, and drop enough poison gas to kill thousands and make practically the whole city uninhabitable."

CHAPTER IV

EARTH'S FOUR ATMOSPHERES

THE earth has four important atmospheres and others of less importance. The principal ones are oxygen, nitrogen, vapor of water, and carbon dioxide, each comporting itself as it would do if the others were not present. There is space between the molecules of each gas, and therefore it is easily compressed. A doubling of its pressure reduces its volume one half.

Composition of Atmospheric Air. It is difficult for the mind to form a picture of the infinitely small molecules of the air. Let us therefore use terms and comparisons that will the more directly appeal to the human senses. First let us imagine each molecule enlarged to the size of a small grain of sand. Then with the molecules from one cubic inch of air transformed into grains of sand we could build a roadway ten feet deep and one hundred feet wide

extending from New York to San Francisco. May one still further grasp the idea of the atom, many of which are required to make up the molecules? If so, the imagination has been stretched to its limits to enable the human mind to comprehend some of the simplest facts with regard to the wonderful fluid in which we live.

Sir William Thomson, afterwards Lord Kelvin, in endeavoring to give relative values that would appeal to the imagination, said that if a drop of water were enlarged to the size of the earth, the molecules of which it is composed would be no larger than cricket balls, and the smallest about the size of small peas.

More than a thousand years before the birth of Christ a great Phœnician philosopher believed that all matter — solids, liquids, and gases — was built up from infinitely small aggregations of atoms. The learned men of Greece enlarged upon his views but this philosophy passed into oblivion with the destruction of Rome and the coming of the Dark Ages, and it was not revived until about one hundred and fifty years ago. The ancients could not prove their theory, while we to-day can count the atoms and determine their size and motions; and, exceedingly small though they be, we no longer believe

them to be indivisible in structure. On the contrary, we know that each atom consists of particles of positive and negative electricity. The negative electrons arrange themselves about a positive electron for a nucleus and, rotating about it as if it were a central sun with planets, constitute an atom. All matter reduced to the ultimate electron is precisely alike. The difference in matter is determined by the number of negative electrons that are attracted and held in place by the positive nucleus that is at the center of each atom of which a particular kind of matter is composed. Each of the ninety-two elements which we believe constitute the ninety-two different forms of simple matter has an atom with its own peculiar type of nucleus, which nucleus differs from those of the others only in the amount of positive electricity it contains. Thus hydrogen, the lightest of all gases, whose weight is taken as unity in measuring the magnitude of other gases, has a nucleus whose positive charge of electricity is only sufficient to attract one negative electron. The next element, helium, has a nucleus with a double positive charge and consequently holds two electrons or planets to pay it homage. In like manner the carbon atom contains six electrons; oxygen, eight; aluminum, thirteen; nitrogen, fourteen; sulphur,

sixteen; iron, twenty-six; copper, twenty-nine; silver, forty-seven; gold, seventy-nine; mercury, eighty; lead, eighty-two; bismuth, eighty-three; radium, eighty-eight; thorium, ninety; and uranium, ninety-two. The chemical union of these elementary forms of matter creates other forms. For instance, the union of two atoms of hydrogen and one of oxygen constitutes a molecule of water. But the gases of the atmosphere are not in chemical union; they exist in the form of a mechanical mixture, each acting as though the others were not present.

It is important that this mixture of gases that constitutes our air be maintained in the right proportion. Only a slight difference in relative amounts might be disastrous to life. An increase in the oxygen would stimulate mental and physical activities and hold the human faculties at a higher tension. Man would accomplish more in a given time, but his span of life would be shortened; and too great an increase in the proportion of this stimulating element would quickly terminate life. Conversely an increase in the nitrogen would render all life more lethargic and man would be slower to act and to think; and too great an increase would smother every living thing.

In addition to the gases named, the air contains

small amounts of many other substances, — argon, nitric acid, ammonia, ozone, xenon, krypton, and neon; as well as organic matter, germs, and dust in suspension. Over the land it contains sulphates in minute quantities, and over the sea and near the seashore salt left from the evaporated spray.

The proportion of each component of the atmosphere by volume of the total atmosphere is different from its proportion by weight. The percentages for the more abundant gases are as follows:

	By Volume	By Weight
Nitrogen	78.04	75.46
Oxygen	20.99	23.19
Argon	0.94	1.30
Carbon dioxide	0.03	0.05
	100.00	100.00

Nitrogen. Its principal functions are to dilute the oxygen and to furnish food to vegetation. It is inert and does not manifest many marked chemical affinities. Its lack of activity is shown by the fact that it will neither support combustion nor burn.

Oxygen. Oxygen, unlike nitrogen, is an active element that readily enters into chemical combination with many other elements, and it is second in quantity to nitrogen. With hydrogen it con-

stitutes eight ninths, by weight, of water; combined with other elements it constitutes forty to fifty per cent. of the crust of the earth. It burns so readily that were it not greatly diluted by an inert gas like nitrogen it would be difficult if not impossible to stop a conflagration when once started. It is the vitalizing principle in all forms of life. By its chemical union with carbon in the tissues of plants and animals it develops the energy manifested in their movements.

In the free air up to about seven miles high there is no variation in the proportion of oxygen. But variations of marked importance to health and life occur in places where ventilation is restricted, and especially where living creatures exist in closed rooms, and where combustion occurs in confined places. The following variations in percentages by volume were found in careful analyses by Robert Angus Smith: On the seashore of Scotland, 20.99; open places in London, 20.95; in a small room where a petroleum lamp had been burning six hours, 20.83; pit of a theater at 11:30 P.M., 20.74; in a court room, 20.65; in mine pits, 20.14. He took samples from one mine that showed 18.27, the candles going out when the amount had decreased to 18.50.

The absorption of oxygen by putrid matter and

by living beings in the process of breathing, and the giving out of carbon dioxide by both explain the deficiency of oxygen that is found over large cities, which is more marked when the air is moving but little and where the city is located in a depression or near swampy lands.

Both animals and plants inhale oxygen and exhale carbon dioxide with the unchanged nitrogen. The process automatically proceeds both night and day. It should not be confused with the opposite action of plants under the influence of sunlight in taking in and decomposing carbon dioxide and expelling pure oxygen.

Carbon Dioxide. It forms the chief food supply of all green-leaved plants. It is as necessary to the life of vegetation as is oxygen in the supporting of animal life. In the ratio of seventy-seven to one hundred there is less of this gas present in the atmosphere in the winter than in the summer; there also is a diurnal maximum and minimum. In the open country the amount averages about 0.035 per cent. by volume. In cities the amount is considerably greater, frequently rising to 0.07, and at times to 0.10 when the wind velocity is too low to scatter the excess amount that accumulates near the ground. Any quantity in excess of 0.06 per cent., especially

if combined with the organic matter exhaled from the lungs and from the pores of the skin by animals and man, is injurious to health. Angus Smith found as much as 0.32 per cent. in crowded theaters, and 2.50 in mines. The latter amount soon would destroy animal life.

Vegetation, in addition to the inhalation of oxygen and the expiration of carbon dioxide at all hours, absorbs the latter during the day, and under the influence of sunlight the green granular matter that constitutes the chlorophyll of the cells of the leaves decomposes it, the plant retaining the carbon and giving out the oxygen. Because of the absence of sunshine the chemical activities of the plant are altered at night and the absorption of carbon dioxide ceases; therefore over the land the maximum amount occurs during the nighttime. This gas is dissolved in seawater and given off with a rise in temperature, which causes the maximum amount over oceans to occur at midday.

Carbon dioxide is 1.50 times as dense as an equal volume of atmospheric air. Its greater density causes it to collect in mines, sewers, cellars, and other low places, unless there is forceful ventilation.

The American cold wave should be welcomed as the mighty scavenger of the air. Its high velocity

and great density cause it to search into cracks, crevices, sewers, and cellars and expel foul accumulations. How sweet and clean the air smells and how vigorous physically and buoyant mentally one feels after a rain and high winds! All nature smiles and every form of life adds its pæan of joy. Rain washes out the carbonic acid gas (carbon dioxide) from the air, with dust and other particles in suspension; and the cold wave enters our places of habitation and drives out the thieving accumulations of poisonous gases that would rob us of health and maintain conditions of morbidity.

It cannot be too forcefully stated that oxygen, the life-sustaining principle of the air, decreases, and carbon dioxide, a poison, increases in air that is breathed, or in air in which lamps or gas jets are burning; and that all places of habitation, especially sleeping rooms, should have a continuous supply of fresh air.

Water Vapor. It is only a little over one half as dense as atmospheric air. In the arid regions of the west it may form only a fraction of one per cent. of the air by weight; while in the humid regions in the eastern part of the United States it may constitute as much as five per cent. The temperature being the same, the same amount is required to

saturate a given space, whether it be a vacuum or whether it be filled with air. Air doubles its capacity for water vapor with each increase of eighteen to twenty degrees. On a hot day in summer, near large bodies of water, it may constitute as much as one twentieth by weight of the lower air, while on a cold day in winter it may form no more than one thousandth part. When the air contains all the water vapor it can hold, it is said to be saturated; no more can be added to it until its temperature is raised, and but a slight lowering of its temperature will precipitate a part of its water vapor in the form of dew, frost, rain, hail, or snow. This is the reason it is usually called water vapor instead of a gas. Under the influence of heat that is below the freezing point, ice and snow may be changed from the solid to the gaseous form, and water vapor may be precipitated as frost or snow without passing through the liquid state.

The Dew Point is the temperature of saturation, — the temperature to which a body of air must be reduced before condensation can occur and some of its water vapor return to the liquid or solid state.

The Relative Humidity is expressed in percentages of the amount necessary to saturate. At a temperature of 32° air may continue to increase its vapor of

water until it contains 2.11 grains per cubic foot, when it will be saturated and its relative humidity be one hundred per cent. If this same air be suddenly raised in temperature to 51° its capacity per cubic foot will be increased to twice what it was at 32°, the 2.11 grains will be equal to only one half the number necessary to saturate, and the relative humidity be expressed by fifty per cent. instead of one hundred per cent. In this way does the capacity of air for water vapor increase. Thus it is seen that the relative humidity of the air may increase during the cooling of nighttime without the addition of any vapor of water, and, in fact, with a decrease. The increase of relative humidity after nightfall is greater in the country than in the city, where the presence of pavements and brick buildings retards the loss of heat.

The Absolute Humidity is expressed in grains the cubic foot. The hygrometer is employed to measure the amount of water vapor.

Hydrogen is the lightest of all known gases. Its density in comparison with ordinary air is only .0692. It is combustible, and when five volumes of atmospheric air are mixed with two volumes of hydrogen the mixture explodes when ignited. It is supplied to the air by active volcanoes and in other

ways, but the speed of its molecules is such that it readily escapes from the earth's attraction and passes outward into space.

Ozone (Greek, ozo, I smell) is highly electrified oxygen, in which the molecules are broken up and reformed so as to contain additional atoms. It is formed by the disruptive discharge of lightning and by the great amount of electricity present in the high levels of the atmosphere, and possibly in minute quantities by the evaporation of fog and water near the earth. It is always found in the presence of waterfalls and spraying fountains. It is a powerful sanitary agent, readily entering into union with decaying matter. This fact accounts for the total absence of ozone from the air of large cities.

Ozone, in the minute quantities found in nature, is healthful, but when breathed in a condensed form it has a highly irritating effect on the mucous surfaces of the respiratory passages, and the quantity is not large that will cause death. The healthfulness of mountain air may be due largely to the increase with elevation in the quantity of ozone and electricity in the air, as well as to the less number of disease germs and dust motes. The invigorating effects of the crisp air of the frosty morning and of

the cold wave in winter may be increased by the activities of ozone.

Ozone has two daily maxima, the principal one occurring between 4 and 9 A.M. The minima occur between 10 A.M. and 1 P.M., and between 10 P.M. and midnight. The winter furnishes an amount greatly in excess of the summer, due not only to the less amount of decaying matter to take up the ozone in winter, but to the higher and more persistent winds mixing the lower and upper air. The amount is greater over the sea than over the land, probably due to the absence of oxidizable matter, which allows the ozone to accumulate over the water. It is more abundant with westerly than with easterly winds, due to the fact that westerly winds have a downward component of motion; but if the westerly winds be weak and the easterly winds come from over a large body of water the conditions may be reversed.

Microbes of the Air. The air transports vast armies of unseen workers. Some are enemies; others are benefactors of the human family. The useful varieties are energetic in clearing away the refuse of animal and vegetable life, in fixing fertilizing gases in the soil, in giving flavor to fruits and proper growth to leguminous crops, in transforming the

crudest must into the best claret, and the poorest tobacco leaf into the fragrant Havana; in curing cheese and butter and fermenting beer, and in a multitude of other useful employments. The malevolent varieties, if they gain lodgment in suitable human tissues before sunlight weakens their virility, disseminate certain forms of disease.

In picking a permanent place of abode, remember that there are many less disease microbes in the air of the open country than in that of the city, and that few are found in the air of mountains, or in that of the ocean. The average number of bacteria in a cubic meter of air in the city of Paris has been found to be 4790, while ten miles away in the country the number was only 345.

Accurate analyses of the air of crowded tenements always have shown large numbers of bacteria, but the number was found to be small in well-ventilated city houses that let in an abundance of sunshine to their interiors. It is better to have color in the cheeks of the occupants than in the furnishings of a house. Curtains and heavy drapery not only furnish a refuge for the microbes of disease, but they may be so hung as to exclude the purifying sunshine. The amount of sunshine is nearly as important as the quantity of air, for most of the microbes of

disease quickly die, or are rendered less virulent, under its influence.

Bacteria exist in small numbers, if at all, at altitudes where snow forms, but snow gathers them as it falls through the lower air. Ice contains bacteria, but not in any such quantity as the water from which it freezes. Ice forms in the open at the surface of the water, or about numerous small particles of matter in suspension, which rise at once to the top as soon as the ice congeals about them in the form of a buoyant covering; meanwhile sediment is continually settling to the bottom, carrying bacteria with it. Ice forms more readily in quiet water, where sedimentation has been most rapid, and where, therefore, there are the fewest bacteria in position to be included. More disease germs exist in river water in winter than in summer, which may be due to the greater disinfecting power of the sun's rays during summer.

Dust Motes of the Air. As the earth pursues its course about the sun, dust rains into its atmosphere from outer space. Meteors that are burned through the heat generated by striking into our air contribute to the supply, as do volcanoes, combustion, spray from the ocean, and matter lifted up by the action of the wind.

Dust from the eruption of Krakatoa was wafted

entirely around the earth, falling upon the decks of ships in all the seas of the world. It affected the colors of the sky for two or three years after the explosion.

As in the case of microbes, the number of dust particles is far greater in cities than in the country, being least on high mountain tops and over the oceans. The air in large cities invariably shows hundreds of thousands of dust motes to the cubic centimeter, that of the village thousands, and that of the open country some hundreds. Dust-free air is also germ-free. Many experiments have shown that air freed of dust motes has at the same time been cleared of the microörganisms that cause disease, putrefaction, and fermentation; and that germ-free flesh or liquids may be indefinitely exposed in such air without fermentation or decay.

How Dust Motes Are Counted. Many of the particles are too small to be seen by the highest powers of the microscope, yet Aitken, by a most ingenious method of making them centers of condensation — that is, making them the nuclei of small raindrops — was able to count the number in a given volume of air. When ordinary air is saturated and then cooled the cloud formed is so dense that it is impossible to count the tiny droplets that form the

cloud. But we can make the number of dust particles (and therefore the number of visible points of condensation) in a given volume of air as small as we wish by mixing a little dusty air with a large amount of dustless air, and we can allow the particles to fall on a bright surface and can count them by means of a lens or microscope. By simply allowing for the proportion of the dustless to the dusty air, and making a corresponding allowance for the dilution, we calculate the number of particles.

Dust Motes and Illumination of the Atmosphere. One of the most important functions of dust motes is the diffusion or scattering of sunlight. What a different world this would be without these tiny inanimate friends of man! If there were no dust in suspension in the air, nothing would be visible except what received direct light, or light reflected from some illumined surface, and the air occupying space between illuminated objects would be practically dark. If the observer be in a room with a powerful electric light he would see the walls and the objects in the room, but if the air were free of dust motes, he would find that the space between him and the walls and between the various objects would be as inky black as is the space between the twinkling stars on a clear night.

Figure 2 is a cubical box, with a glass front. If a glutinous substance be spread over the bottom and the box allowed to remain quiescent for from five to seven days the dust motes will slowly settle down and attach themselves to the bottom. The air then will be what is called "optically pure." Now, if it be taken into a dark room and an inclosed lamp at *a* be allowed to send a beam of light into the window at *b* and out at *c*, it will be found that the interior remains dark no matter how powerful the light from the lamp. The light is seen to enter and to leave but where it encounters the dust-free air there is nothing to scatter the light rays and they remain invisible to the eye.

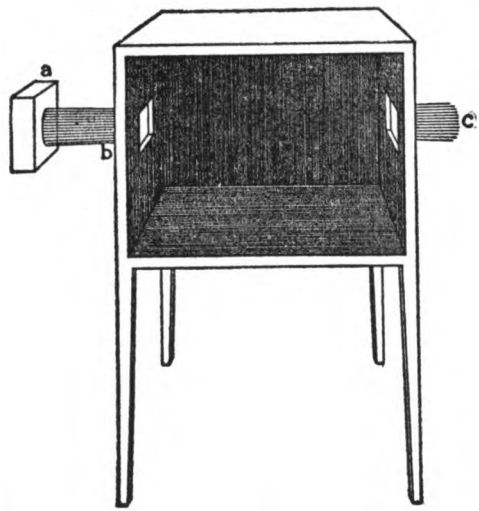


FIG. 2. — Showing light from lamp *a* passing into dust-free air at *b*, and passing out at *c* without illuminating the interior.

Dust Motes Prolong Twilight. The bending or

refraction of light as the sun's rays pass obliquely through the air at sunrise and at sunset displaces the apparent position of the sun, elevating it by an amount about equal to its own apparent diameter, so that one may see it and receive its light when geometrically it is entirely below the horizon. A little later in the evening and its rays fall upon the upper air too obliquely to be bent down to the earth by refraction; but darkness does not yet ensue, for the rays are scattered by the dust motes and possibly by the molecules of the gases and sent downward from particle to particle, resulting in a soft shimmering light that almost imperceptibly fades away, and which in higher latitudes may last for hours.

CHAPTER V

LIGHT, HEAT, AND TEMPERATURE

MORE WONDERFUL THAN ANY FICTION ARE THE FACT OF INVISIBLE LIGHT, AND THE DIFFERENCE BETWEEN HEAT AND TEMPERATURE

THE heat that escapes from the earth's interior is minute in comparison to that received from the sun, which is the main source of the earth's supply. Heat is manifested by the motions of the molecules of matter, whether solid, liquid, or gaseous. It is transmitted through space in some mysterious manner, for space is practically void of an atmosphere. One cannot conceive of motion taking place in a void, for there is nothing to move. Therefore it is assumed that interstellar space must be filled with a transmitting medium; to this the name of ether has been given. Nothing is known of its structure, but it is believed that it penetrates all bodies and fills the space between their molecules.

How Heat and Light Reach the Earth. The heat of the sun is some forty-six thousand times as intense as is the heat of the earth. The violent agitations of the molecules of the sun's hot atmosphere impart vibrations to the ether of space, which decrease in effectiveness inversely as the square of the distance; that is to say, that if the earth were twice as far from the sun as it is, the intensity of the solar rays would be one fourth of what they are now. These vibrations are called solar energy. They pass through space without perceptibly warming or lighting it. When they encounter the molecules of the earth's atmosphere, and the dust and cloud in suspension in the air, or impinge upon the solid matter of the earth, they are transmuted back into molecular agitations, and manifest themselves in a multitude of forms, such as heat, light, chemical rays, electricity, etc.

The Difference between Heat and Temperature. The agitation of the molecules of a substance set up by the absorption of heat is indicated by temperature, which gives no measure of the quantity of heat absorbed, the quantity varying widely for different kinds of matter. The amount of heat necessary to raise one pound of water 1° F. is the heat unit generally employed in commerce; but in scientific

research the amount necessary to raise one gram of water 1° Centigrade is the unit of heat best adapted to use. It is called the gram-calorie.

Let us take a glass filled with boiling water. You see the glass and the water because they reflect to the eye light waves received from some source, — possibly the sunlight that is diffused by the dust motes of the air into the room through the window. But the glass and the water radiate other waves to which the eye is not sensible; these invisible long heat waves may be felt by the nerves of the hand. They warm all matter upon which they fall by adding to the agitation of the molecules of which it is composed; but they do not warm all matter equally. The waves that reach dark bodies are broken up; that is to say, absorbed. Their energy is transmuted into sensible heat, and in the place of the waves we have molecular vibrations in the matter, which are made manifest by a rise in its temperature. Dark rough surfaces more completely absorb the waves and therefore rise to a higher temperature than the same surfaces when smooth. When the waves encounter bright and highly polished surfaces the effect is quite different; then most of them are reflected away and therefore warm the matter but little. These reflected waves are not broken

up, but on the contrary start off in some new direction, possibly falling upon and warming some matter more receptive to their influence. The higher the polish the more completely are the waves reflected.

Difference between Light Waves, Heat Waves, and Sound Waves. The light and the heat waves of the ether are infinitesimal ripples as compared to the backward and forward pulsations that constitute the sound waves of the air. Within a space of one inch there are sixty-six thousand of the violet waves of light, which are the shortest etheric vibrations to which the human eye responds, and over thirty thousand of the red waves, the longest that affect the eye; while the sound waves of the air vary from about one foot for the shrill notes of the human voice to four feet for the middle C of the pianoforte. A shrill whistle produces waves of about one half inch. There are twenty-two thousand of certain heat waves to the inch, and these, like some of the light waves of the ether, are invisible.

There is also a vast difference between the velocity of vibration of the air waves and those of the ether. The human ear is sensitive to sound waves of somewhere between twenty-nine per second to thirty-eight thousand per second; while the eye responds to light

waves of from five hundred million to one billion per second. Some ears are better adjusted to the low vibrations and some to the high, and the ears of no one hear any but a small part of the melody of a great symphony. Tyndall could hear the sharp chirp of thousands of insects that were inaudible to his guide as the two climbed the Alps, but the guide's ears responded to the long, slow waves that came from the dull tread of the donkey's hoofs farther up the mountain, which waves the scientist was unable to hear. Likewise some eyes are able to penetrate far into the violet, or the red, or both, and some are unable to distinguish between certain colors.

Chemical Rays of Light. The chemical or photographic rays have still shorter waves than the violet. They produce special physiological effects in vegetable and animal tissues, and, acting upon particular kinds of matter, they cause fluorescence, which is the property possessed by some bodies of giving off, when illuminated, light of a color different from their own and from that of the light that illuminates them. These chemical rays are sometimes called ultra-violet rays.

Invisible Light. From a reading of the immediately preceding paragraphs one may be prepared for the startling statement that there is such a thing

as invisible light. Vibrations of the ether that move slower than those that give to the eye the sensation of red are invisible, as are those that move faster than the violet rays, and it is certain that neither the eye of man nor of animal ever will see but a small part of the beauty of a landscape or the delicate coloring of a flower. The eye only takes in and renders sensible to the brain the red, orange, yellow, green, blue, indigo, violet, and their various tints, but the delicate instruments of science reveal many other colors. One sees as through a glass darkly, for the gentle signals that might reveal the beauties of Paradise fall upon the eye unheeded. A keener vision and a more complete appreciation of the beauties and the wonders of the universe await one on the other side of the gauzy veil of immortality. The finger tips of the outstretched arms may span the river of life and the ethereal breath of loved ones may be caressing one's cheek. The music of the spheres is not a myth; the lily or the rose as it opens its petals to receive the benediction of the morning sun may give forth a veritable pæan of joy. A rose bush may be a grander symphony than anything that Beethoven ever wrote. What to us is the invisible light may be the illumination that guides the sweep of the angels' wings.

How Heat Moves through or Is Transmitted by Matter. Heat passes by contact from the warmer to the colder molecules of a body. This action is called conduction. When one end of a bar of iron is held in a fire, the end away from the fire soon becomes too hot to hold in the hand, because heat is rapidly transferred from the hot portion of the bar to the cooler portion by conduction, showing that iron is a good conductor. On the other hand, the end of a stick of wood can be held in the fire until it is completely consumed without the other end becoming too warm to hold, indicating that wood is a poor conductor. Metals are the best conductors, silver leading the list, with copper second. Snow and ice and fibrous and porous substances are poor conductors, and are called insulators. Air and water are also poor conductors. The fur of animals and the feathers of birds protect against the rapid loss of heat because they contain numerous interstices filled with air, a poor conductor. Heat is lost by radiation when the molecules of matter set up vibration in the ether. The atmosphere itself performs this function on a large scale when the sky is cloudless, so that radiated heat is not absorbed by the cloud covering and its loss into space restricted. When air or water is

not evenly or homogeneously heated a circulation is set up in which the colder part settles down and the warmer rises. This is called convection. The air that is heated by contact with a stove rises and passes along the ceiling to the colder parts of the room, gradually parting with its heat until it is no warmer than the air next adjacent to it, and slowly settling to the floor as the cold air beneath it moves toward the stove, is warmed and sent aloft, the first air finally making a complete circuit and returning to the stove again. In this way the heat is distributed by convection throughout the whole room. When one part of the earth's surface becomes hotter than another a similar action takes place on a large scale. The region of greater temperature warms the air above it, and the surrounding denser air flows in along the surface, forcing the lighter air to rise, when it in turn is similarly warmed and driven up.

The clear waters of lakes and rivers and of the ocean permit the passage of heat waves to a considerable depth before they are completely absorbed. On a cold day in winter, when the sun is shining brightly, a room with spacious windows may become as warm as though heated by a furnace, simply by the capacity of the glass in the windows to transmit

the heat waves of the sun without considerable absorption, and at the same time prevent the escape of the longer heat waves that are radiated from the interior walls of the room. This capacity of matter to transmit heat waves without absorption is called diathermancy. The clear atmosphere is an exceedingly good transmitter, and rock salt is one of the best of all solids.

The capacity of a body to transmit light without absorbing it and becoming luminous is called transparency. Air freed of dust motes is almost perfectly transparent. In this state it is said to be optically pure. But the ordinary air of nature, with its moisture and dust, absorbs most of the blue wave lengths and also many of the longer ones of the other colors of the spectrum.

The capacity of a body for heat is called its specific heat. With but few exceptions the specific heats of liquids are much greater than those of solids or gases. It requires ten times the quantity of heat to raise a pound of water one degree that it does a pound of iron. Ice has the greatest specific heat of any of the solids, except paraffin and wood.

When a solid is melted or a liquid vaporized a large amount of heat becomes latent, insensible to the touch; it disappears as heat. This is one of

the most wonderful of the phenomena of nature. It matters not how long the time may be, an hour, a day, a year, or a thousand years after the solid is melted or the liquid turned to vapor, so soon as the vapor returns to the liquid state or the liquid to a solid condition, the latent heat becomes sensible in exactly the same degree in which it previously existed. Let us illustrate with a pound of ice at zero F. Sixteen heat units, or sixteen times as much heat as is required to raise one pound of water one degree, must be absorbed by this pound of ice to raise its temperature to the melting point (32°); and then one hundred forty-four more heat units must be absorbed to so far overcome the tendency of the molecules to adhere, or remain together, that the molecules may roll the one about the other in the liquid form, but with this important difference: the one hundred forty-four units become latent and do not, therefore, cause any increase in temperature, as the sixteen heat units did in raising the temperature of the ice. The large quantity of heat required to change the ice to a liquid is called the latent heat of melting. Any further addition of heat after the melting is complete causes an increase in temperature, and one hundred eighty heat units will raise it to the boiling point. Water

boils at 212° at sea level and normal pressure; that is to say, at that temperature the agitation of the molecules of water is so great as to overcome both cohesion and the weight with which the air presses down upon them, and cause them to fly away in the form of steam, which is invisible when confined inside a boiler. But the entire pound of water is not instantly changed to the gaseous condition, for with the sending off of the first few molecules some heat is rendered latent, and more must be supplied or the boiling ceases; in fact the enormous quantity of 964.62 heat units must be supplied to entirely change the pound of water to steam, but at no time does the temperature rise above 212°. As in the former case of changing the solid to a liquid, a large amount of heat becomes latent; in this case it is called the latent heat of vaporization.

Now carefully fix in the mind that a liquid does not need to be raised to its boiling point before vaporization begins, for it operates at all temperatures, even after the liquid is frozen, but much more rapidly from the liquid. If one wishes to test this: weigh a piece of ice during very cold weather. Then leave it out in a temperature that is below freezing for several days, and on weighing again it will be found that the ice has lost weight. All

evaporation produces a cooling effect because of the heat that is rendered latent in the process of changing the liquid or the solid to a gaseous form. The drier the air the greater is the cooling effected by keeping the surface wetted, and the cooling is accelerated by placing the wet object where there is a free circulation of air.

A wooden water bucket that has been soaked for a day or two so that every part of the wood is saturated with water, will, if kept closed, keep water all day in the open field practically as cool as when it left the deep well, and often cooler. Not enough use is made of cooling by evaporation by those who have not ice in the summer. Inexpensive and fairly effective refrigerators may be made, by any mechanic, of lattice-work sides covered with any thick fabric and kept moist, which would keep milk, butter, fruit, vegetables, and cooked meats in good condition if placed in a hallway with a good circulation of air, or in any shady place with good ventilation.

Most solids expand with gain in temperature and therefore possess greater volume in the liquid form than in the solid, and the temperature of their melting points rises as they are subjected to increasing pressure. The law reverses when applied

to ice, which contracts in melting. To few is it known that a skater on ice really rides upon water molecules, for the sharp edge of the skate, when applied to the ice under the weight of one's body, is lubricated by the slight melting of the ice in immediate contact with the skate, the molecules of water returning to the form of ice as soon as the skater passes and the pressure is relieved. The strange phenomenon may be witnessed by passing a wire through a block of ice without severing it into two pieces, by attaching heavy weights to the two ends of the wire and suspending it across the ice, the ice slowly melting as the result of the pressure applied by the underside of the wire and freezing molecules closing the space on top of the wire. By this process do we account for the moving of glaciers down tortuous valleys as though they were liquids.

Altitude Measured by Change in Boiling Point of Water. The boiling point of water at sea level and ordinary air pressure is 212°. If the pressure of the atmosphere were increased to about thirty pounds, instead of about fifteen to the square inch it would be necessary to raise water to 250° before boiling would begin. The changes of air pressure due to the passage of the severe storms of winter may cause the boiling point of water to vary from

207° to 215°. This knowledge may be useful in measuring the heights of mountains, although the method does not give close results. The decrease of pressure with altitude lowers the boiling point, the amount being approximately one degree for each 555 feet of ascent. The best results may be secured by having a person at the base of the mountain, where the elevation above sea level is known, determine the boiling point at the same time that a person on the mountain top does. The thermometers should be read closely to the fraction of a degree.

With the barometer at its normal height of thirty inches, air at 60° will instantly rise to the phenomenal temperature of 175.50 if it be confined and its pressure doubled, and it will diminish to one half of its former volume. But if its pressure be diminished one half, its volume will expand to double its original size and its temperature will fall from 60° to 2.4°. From these facts the reader would naturally expect to find low pressure of the atmosphere accompanying cold waves and high pressure to be coincident with warm conditions, which is exactly the reverse of what actually occurs in the free air of nature. This apparent contradiction will be made plain in the treatment of cold waves, page 124.

A temperature of 459° on the Fahrenheit scale and 273.1° on the Centigrade represents what is called absolute zero. It is supposed to be the temperature at which there is no motion of the molecules of matter. Bodies or planets without atmospheres have temperatures approaching absolute zero, for there is no protecting envelope to absorb heat or to prevent the instant radiation into space of that which impinges upon the body. Our moon is an illustration, and notwithstanding the fierce beating upon its surface of the solar energy it remains incased in the intense cold of space.

The thermometer is the instrument that measures temperature. It was not until eighty-seven years after Columbus discovered America that Galileo discovered the principle of the thermometer. This first instrument was crude. It consisted of a glass bulb, containing air, terminating below in a long glass tube, which dipped into a vessel containing colored water. When the temperature fell the contraction of the air in the bulb caused the water to rise in the tube, and when the temperature rose the expansion of the air forced the water to a lower level. Galileo also invented the alcohol thermometer in 1611, but the determination of the zero and some fixed point above it, by which to graduate

the scale, took years to evolve. The modern alcohol and mercury thermometers consist of a bulb filled with the liquid, and a tube partly filled, the upper part being a tolerably complete vacuum, allowing the liquid freedom of movement up and down the tube. When a tube is broken one is surprised to see that the diameter of the bore is less than that of the smallest fuzzy hair from the back of the hand. The size of the column of mercury is magnified by the action of light passing through the glass of the tube.

Temperatures are usually taken in the shade. The instrument should be free from all bodies that could conduct heat to it, and it should have free circulation of air about it.

In a complete meteorological station automatically recording instruments, too complicated for the use of the layman, record for each moment of time the temperature of the air and its pressure, the periods of sunshine, the duration and the amount of rainfall, and the direction and velocity of the wind.

CHAPTER VI

THE ADVANTAGE OF TAKING WEATHER OBSERVATIONS AND APPLYING THEM TO ONE'S PERSONAL NEEDS

FORECASTS MADE FROM THE ANEROID BAROMETER — COLDS PREVENTED BY MOISTENING AIR IN LIVING ROOMS — a CRIMINAL HANGED AND AN INNOCENT MAN FREED BY WEATHER RECORDS

Observations from Kites. It is strange that the Chinese, who have been flying kites many thousand years, should not have made improvements in the primitive construction of these devices. It remained for Wendham, in 1866, to perceive the advantage of superimposing two or more planes, one above the other, for the purpose of securing a larger area of sustaining surface. After examining Figure 3 almost any one can build an efficient kite. Heights of two to three thousand feet may be reached by using cable-laid twine No. 24, but in order to gain great altitudes pianoforte wire must be used. Soft pine is the best and most available material.

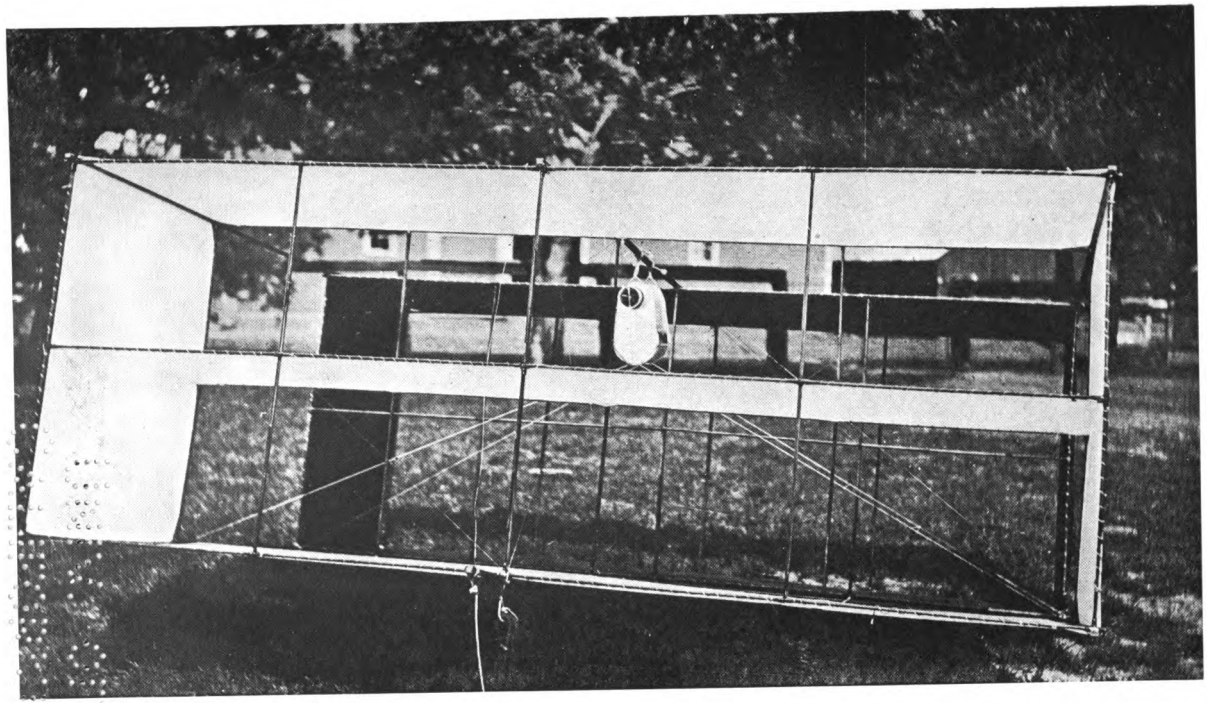


FIG. 3. — STANDARD WEATHER BUREAU KITE.

Spruce is stronger, but more difficult to secure. The sticks should be straight-grained. The cloth may be silk or the stronger and finer grades of cotton. It should be torn, not cut. The ends will then be true and square with the fiber of the cloth. Kites are used not only to secure weather observations, but they have been used to draw sleds in the Arctic region, and to draw wagons and boats. By adjusting the points at which the pulling cords are attached to the boat an ingenious sailor is able to proceed nearly at right angles to the direction of the wind.

When it is known that a box kite having only sixty square feet of sustaining surface, flying at a considerable height, may lift a person of ordinary size, one is impressed with the idea that vessels of commerce might employ kites of large dimensions to increase the speed of sailing ships. The kites would fly in a stratum whose velocity is not restricted by friction with the surface of the water.

To launch a kite: run out about one hundred and fifty feet of the cord or wire while the kite is held by an assistant, who should give the kite a toss upward in the direction in which it must go. It is important that it be cast off directly in line with

the wind. If the wind is light it may be necessary to run a short distance with a long line out in order to effect a launching.

Voluntary Weather Observers. There are more than three thousand voluntary or coöperating observers in the U. S. Weather Bureau. They receive no compensation other than the publications of the Bureau. They are required to read their instruments but once each day, as maximum and minimum thermometers record the highest and the lowest temperatures since they were last read and set. About sunset is the most satisfactory time for making the readings, since the thermometers will then show both the extremes for the past twenty-four hours. As a rule but one voluntary observer is accepted for a county. They are furnished without charge with maximum and minimum thermometers, instrument shelters and rain gauges, but not with wind vanes, anemometers for recording direction and velocity of wind, or barometers. But those who desire to become expert in forecasting the weather, as all may who study the chapter on forecasting, should equip themselves with an aneroid barometer, so that they may note the changes in the pressure of the air.

An instrument shelter (Figure 4) is employed to

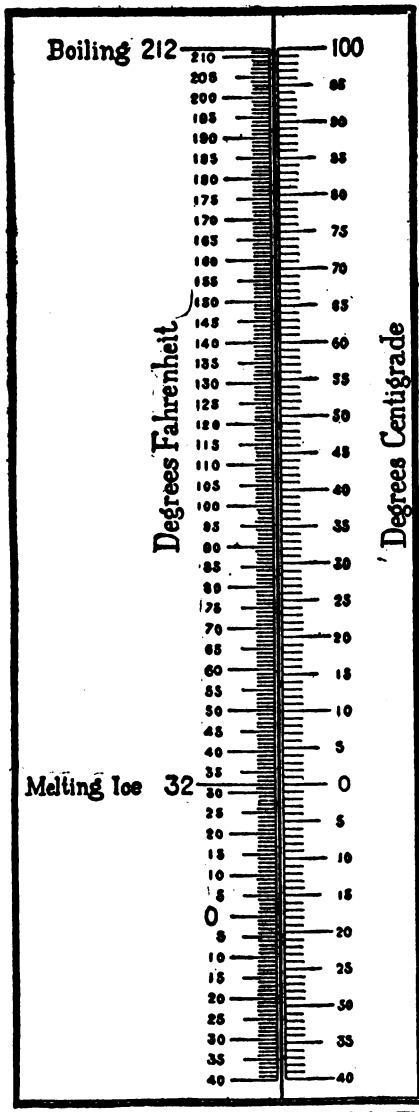


Fig. 5. — Comparison of the Thermometer Scales.

COMPARISON OF THERMOMETER SCALES

A little study of the accompanying information and diagram will enable any one to form a clear idea of the various thermometer scales and to convert temperatures from one scale to another.

Table of fixed points.

Scale.	Temperature of freezing ice.	Temperature of boiling water.	No. of degrees between freezing and boiling point.
Centigrade.	0	100	100
Reaumur..	0	80	80
Fahrenheit	32	212	180

Only Fahrenheit and Centigrade scales are in general use, and the accompanying plate is designed to enable observers to convert temperature readings from one scale to the other without resorting to a mathematical formula.

For accurate and precise reductions between the different scales the following rules should be used:

1. To convert Fahrenheit to Centigrade: Subtract 32 and multiply by five ninths.
2. To convert Centigrade to Fahrenheit: Multiply by nine fifths and add 32.
3. To convert Fahrenheit to Reaumur: Subtract 32 and multiply by four ninths.
4. To convert Reaumur to Fahrenheit: Multiply by nine fourths and add 32.
5. To convert Centigrade to Reaumur: Multiply by four fifths.
6. To convert Reaumur to Centigrade: Multiply by five fourths.

screen off the direct and reflected sunshine, and to keep the thermometers dry. This shelter is a box with louvered sides, constructed in such form that there is a free circulation of air through it. It should be exposed in an open space as far away from buildings as may be convenient, or on a housetop, and be as free from shadows as possible. If such position cannot be secured, then place it on the north side of a building.

Comparison of Centigrade and Fahrenheit. Only Fahrenheit and Centigrade are in general use. Figure 5 is designed to enable observers to convert temperature readings from one scale to the other without resorting to a mathematical formula. For precise reductions the following rules apply:

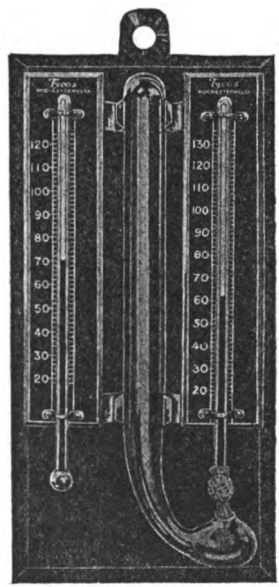


FIG. 6. — Dry and Wet Bulb Thermometers.

To convert Fahrenheit to Centigrade: Subtract 32 and multiply by five ninths.

To convert Centigrade to Fahrenheit: Multiply by nine fifths and add 32.

Humidity Affects Health and Complexion. The

RELATIVE HUMIDITY TABLES

Temperature Readings in Degrees Fahrenheit. Relative Humidity Readings in Per Cent. Barometric Pressure 29.0 inches.

READINGS OF DRY BULB THERMOMETER	DIFFERENCE IN DEGREES FAHRENHEIT BETWEEN WET AND DRY BULB THERMOMETERS.																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
20	85	70	56	42	28	14															
21	86	71	57	44	30	17	3														
22	86	72	59	45	32	19	7														
23	87	73	60	47	34	22	10														
24	87	74	61	49	36	24	12	0													
25	87	75	63	50	38	27	15	4													
26	88	75	64	52	40	29	18	7													
27	88	76	65	53	42	31	20	9													
28	88	77	66	55	44	33	23	12	2												
29	89	78	67	56	45	35	25	15	5												
30	89	78	68	57	47	37	27	17	8												
31	89	79	69	58	49	39	29	20	10	1											
32	90	79	69	60	50	41	31	22	13	4											
33	90	80	71	61	52	42	33	24	16	7											
34	90	81	72	62	53	44	35	27	18	9	1										
35	91	82	73	64	55	46	37	29	20	12	4										
36	91	82	73	65	56	48	39	31	23	14	6										
37	91	83	74	66	58	49	41	33	25	17	9	1									
38	91	83	75	67	59	51	43	35	27	19	12	4									
39	92	84	76	68	60	52	44	37	29	21	14	7									
40	92	84	76	68	61	53	46	38	31	23	16	9	2								
41	92	84	77	69	62	54	47	40	33	26	18	11	5								
42	92	85	77	70	62	55	48	41	34	28	21	14	7	0							
43	92	85	78	70	63	56	49	43	36	29	23	16	9	3							
44	93	85	78	71	64	57	51	44	37	31	24	18	12	5							
45	93	86	79	71	65	58	52	45	39	33	26	20	14	8	2						
46	93	86	79	72	65	59	53	46	40	34	28	22	16	10	4						
47	93	86	79	73	66	60	54	47	41	35	29	23	17	12	6	1					
48	93	87	80	73	67	60	54	48	42	36	31	25	19	14	8	3					
49	93	87	80	74	67	61	55	49	43	37	32	26	21	15	10	5					

RELATIVE HUMIDITY TABLES—Continued

Temperature Readings in Degrees Fahrenheit. Relative Humidity Readings in Per Cent. Barometric Pressure 29.0 inches.

READINGS OF DRY BULB THERMOMETER	DIFFERENCE IN DEGREES FAHRENHEIT BETWEEN WET AND DRY BULB THERMOMETERS.																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
50	93	87	81	74	68	62	56	50	44	39	33	28	22	17	12	7	2				
51	94	87	81	75	69	63	57	51	45	40	35	29	24	19	14	9	4				
52	94	88	81	75	69	63	58	52	46	41	36	30	25	20	15	10	6	0			
53	94	88	82	75	70	64	58	53	47	42	37	32	27	22	17	12	7	3			
54	94	88	82	76	70	65	59	54	48	43	38	33	28	23	18	14	9	5	0		
55	94	88	82	76	71	65	60	55	49	44	39	34	29	25	20	15	11	6	2		
56	94	88	82	77	71	66	61	55	50	45	40	35	31	26	21	17	12	8	4		
57	94	88	83	77	72	66	61	56	51	46	41	36	32	27	23	18	14	10	5	1	
58	94	89	83	77	72	67	62	57	52	47	42	38	33	28	24	20	15	11	7	3	
59	94	89	83	78	73	68	63	58	53	48	43	39	34	30	25	21	17	13	9	5	1
60	94	89	84	78	73	68	63	58	53	49	44	40	35	31	27	22	18	14	10	6	2
61	94	89	84	79	74	68	64	59	54	50	45	40	36	32	28	24	20	16	12	8	4
62	94	89	84	79	74	69	64	60	55	50	46	41	37	33	29	25	21	17	13	9	6
63	95	90	84	79	74	70	65	60	56	51	47	42	38	34	30	26	22	18	14	11	7
64	95	90	85	79	75	70	66	61	56	52	48	43	39	35	31	27	23	20	16	12	9
65	95	90	85	80	75	70	66	62	57	53	48	44	40	36	32	28	25	21	17	13	10
66	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33	29	26	22	18	15	11
67	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34	30	27	23	20	16	13
68	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35	31	28	24	21	17	14
69	95	90	86	81	77	72	68	64	59	55	51	47	44	40	36	32	29	25	22	19	16
70	95	90	86	81	77	72	68	64	60	56	52	48	44	40	37	33	30	26	23	20	17
71	95	90	86	82	77	73	69	64	60	56	53	49	45	41	38	34	31	27	24	21	18
72	95	91	86	82	78	73	69	65	61	57	53	49	46	42	39	35	32	28	25	22	19
73	95	91	86	82	78	73	69	65	61	58	54	50	46	43	40	36	33	29	26	23	20
74	95	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	21
75	96	91	87	82	78	74	70	66	63	59	55	51	48	44	41	38	34	31	28	25	22
76	96	91	87	83	78	74	70	67	63	59	55	52	48	45	42	38	35	32	29	26	23
77	96	91	87	83	79	75	71	67	63	60	56	52	49	46	42	39	36	33	30	27	24
78	96	91	87	83	79	75	71	67	64	60	57	53	50	46	43	40	37	34	31	28	26
79	96	91	87	83	79	75	71	68	64	60	57	54	50	47	44	41	37	34	31	28	26

RELATIVE HUMIDITY TABLE—Continued

Temperature Readings in Degrees Fahrenheit. Relative Humidity Readings in Per Cent. Barometer Pressure 29 0 inches.

READINGS OF DRY BULB THERMOMETER	DIFFERENCE IN DEGREES FAHRENHEIT BETWEEN WET AND DRY BULB THERMOMETERS.																										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
80	96	91	87	83	79	76	72	68	64	61	57	54	51	47	44	41	38	35	32	29	27	24	21	18	16	13	11	8	6	4
82	96	92	88	84	80	76	72	69	65	62	58	55	52	49	46	43	40	37	34	31	28	25	23	20	18	15	13	10	8	6
84	96	92	88	84	80	77	73	70	66	63	59	56	53	50	47	44	41	38	35	32	30	27	25	22	20	17	15	12	10	8
86	96	92	88	85	81	77	74	70	67	63	60	57	54	51	48	45	42	39	37	34	31	29	26	24	21	19	17	14	12	10
88	96	92	88	85	81	78	74	71	67	64	61	58	55	52	49	46	43	41	38	35	33	30	28	25	23	21	18	16	14	12
90	96	92	89	85	81	78	75	71	68	65	62	59	56	53	50	47	44	42	39	37	34	32	29	27	24	22	20	18	16	14
92	96	92	89	85	82	78	75	72	69	65	62	59	57	54	51	48	45	43	40	38	35	33	30	28	26	24	22	19	17	15
94	96	93	89	86	82	79	75	72	69	66	63	60	57	54	52	49	46	44	41	39	36	34	32	29	27	25	23	21	19	17
96	96	93	89	86	82	79	76	73	70	67	64	61	58	55	53	50	47	45	42	40	37	35	33	31	29	26	24	22	20	18
98	96	93	89	86	83	79	76	73	70	67	64	61	59	56	53	51	48	46	43	41	39	36	34	32	30	28	26	24	22	20
100	96	93	90	86	83	80	77	74	71	68	65	62	59	57	54	52	49	47	44	42	40	37	35	33	31	29	27	25	23	21
102	96	93	90	86	83	80	77	74	71	68	65	63	60	57	55	52	50	47	45	43	41	38	36	34	32	30	28	26	24	22
104	97	93	90	87	84	80	77	74	72	69	66	63	61	58	56	53	51	48	46	44	41	39	37	35	33	31	29	27	25	24
106	97	93	90	87	84	81	78	75	72	69	66	64	61	59	56	54	51	49	47	45	42	40	38	36	34	32	30	28	27	25
108	97	93	90	87	84	81	78	75	72	70	67	64	62	59	57	54	52	50	47	45	43	41	39	37	35	33	31	29	28	26
110	97	95	90	87	84	81	78	76	73	70	67	65	62	60	57	55	53	50	48	46	44	42	40	38	36	34	32	30	29	27
112	97	94	90	87	84	82	79	76	73	70	68	65	63	60	58	56	53	51	49	47	45	43	41	39	37	35	33	31	30	28
114	97	94	91	88	85	82	79	76	74	71	68	66	63	61	59	56	54	52	50	48	45	43	41	40	38	36	34	32	31	29
116	97	94	91	88	85	83	79	77	74	71	69	66	64	61	59	57	55	52	50	48	46	44	42	40	38	37	35	33	31	30
118	97	94	91	88	85	83	79	77	74	72	69	67	64	62	60	57	55	53	51	49	47	45	43	41	39	37	36	34	32	31
120	97	94	91	88	85	83	80	77	74	72	69	67	65	62	60	58	56	54	51	49	47	46	44	42	40	38	36	35	33	31
122	97	94	91	88	85	83	80	77	75	72	70	67	65	63	61	58	56	54	52	50	48	46	44	42	41	39	37	36	34	32
124	97	94	91	88	86	83	80	78	75	73	70	68	65	63	61	59	57	55	53	51	49	47	45	43	41	40	38	36	34	33
126	97	94	91	89	86	83	81	78	75	73	71	68	66	64	62	59	57	55	53	51	49	47	46	44	42	40	39	37	35	34
128	97	94	91	89	86	83	81	78	76	73	71	69	66	64	62	60	58	56	54	52	50	48	46	44	43	41	39	38	36	34
130	97	94	92	89	86	84	81	78	76	74	71	69	67	65	62	60	58	56	54	52	50	49	47	45	43	42	40	38	37	35
132	97	94	92	89	86	84	81	79	76	74	72	69	67	65	63	61	59	57	55	53	51	49	47	46	44	42	41	39	37	36
134	97	94	92	89	86	84	81	79	76	74	72	70	67	65	63	61	59	57	55	53	51	50	48	46	44	43	41	40	38	36
136	97	94	92	89	87	84	82	79	77	74	72	70	68	66	64	61	59	58	56	54	52	50	48	47	45	43	42	40	39	37
138	97	94	92	89	87	84	82	79	77	75	72	70	68	66	64	62	60	58	56	54	52	51	49	47	45	44	42	41	39	38
140	97	95	92	89	87	84	82	80	77	75	73	71	68	66	64	62	60	58	56	55	53	51	49	48	46	44	43	41	40	38

importance to health of maintaining a proper humidity in living quarters during the winter months and during all months in the arid and semi-arid regions of the West is not fully appreciated. Each habitation should be supplied with one to several hygrometers (Fig. 6), and frequent readings should be taken of the dry and the wet bulb thermometers so as to be familiar with the conditions under which one is living.

A relative humidity of between sixty-five and seventy per cent. should be maintained in all living and sleeping rooms, if one is to escape colds, catarrh, and possibly pneumonia. Some nervous disorders are aggravated if not actually caused by the dryness of the air in steam and other heated apartments during the time that the windows are closed in cold weather. The vanity of the female sex is appealed to with the statement that nothing is more essential to securing and preserving a good complexion than the maintaining of a proper humidity in one's own room. Efficient and simple and inexpensive humidifiers are now coming on the market. They are almost as necessary to the health of a household as stoves and furnaces. Often a right degree of moisture can be created by leaving clean water in the bathtub and in all wash basins and sinks.

One may be surprised on taking humidity observations to find how quickly it increases in rooms two or three removed from the bathroom after water is run into the tub, and especially if the shower spray is turned on and allowed to operate for a few minutes.

In cold weather we maintain the aridity of the Sahara Desert in our hot, steam-heated apartments, with a relative humidity of less than thirty per cent. Is it any wonder that when we step from this atmosphere into the cold outside air, with a humidity of seventy per cent., the violent change is productive of harm, particularly to the delicate mucous membranes of the upper air passages, which have been irritated and their powers of resistance weakened by the dryness within? The period of pneumonia is the season of artificial heat in living rooms — or, more properly speaking, the period of indoor desert aridity.

Save Fuel by Moistening Air. If a room at 68° is not warm enough for any healthy person it is because the humidity is too low, and water should be evaporated to bring the moisture up to sixty-five or seventy per cent. of saturation. Water instead of coal should be used to make rooms comfortable when the temperature has reached 68°. Ten to fifteen per cent. of fuel could be saved in the heating of places of habitation if the air were

properly and healthfully humidified. The reason for this is that if the air is dry the heat passes through it and warms it but little. Moisture stops the radiated heat that would be lost, absorbs it, and holds it at the place where it is needed. It has precisely the same effect as a soft wool blanket wrapped about the body of each person. The dry air permits such a rapid evaporation from the human body that one may actually feel colder with a dry air heated to 75° than in a moist air at 66° or 68°. Water is cheaper than coal, and in this matter much more healthful.

The cooling effect produced by a draught does not necessarily arise from the wind being cooler, for it may be actually warmer, but arises from the rapid evaporation it causes on the surface of the skin. Vapor of water forms a blanket about the earth and prevents it from scorching during the day and freezing during the night.

How to Forecast Weather with Only an Aneroid Barometer. No one except an expert observer should use the mercurial barometer. The aneroid will answer as well for the purpose of forecasting from a single instrument; it is cheaper and less complicated. First learn your elevation above sea level; then add to the observed reading of your instrument

.10 for each one hundred feet elevation. Note the fall or rise and the direction of the wind and with the aid of the table on page 76 highly satisfactory forecasts may be made by any intelligent person. Skill will come with practice. Write down your forecasts each day as you make them and the following day note in a blank space left for the purpose the success or failure of your effort. Thus will you profit by your mistakes.

As a rule winds from the east quadrants and falling barometer indicate foul weather, and winds shifting to the west quadrants indicate clearing and fair weather. The rapidity of the storm's approach and its severity are indicated by the rate and the amount in the fall of the barometer. This applies to the Mississippi Valley and eastward to the Atlantic Ocean. Conditions are different in the Rocky Mountains, on the plateau of the mountains, and on the eastern Rocky Mountain slope, where precipitation seldom begins until after the barometer begins to rise after a fall, and the winds have shifted to the northwest.

Keep in mind that storms are great atmospheric eddies drifting from the west, with the winds blowing cyclonically toward the center; that when your wind is northeast the center of the storm is south-

Wind Direction	Barometer Reduced to Sea Level	Character of Weather Indicated
SW. to NW.	30.10 to 30.20 and steady.	Fair, with slight temperature changes, for 1 to 2 days.
SW. to NW.	30.10 to 30.20 and rising rapidly.	Fair, followed within 2 days by rain.
SW. to NW.	30.20 and above and stationary.	Continued fair, with no decided temperature change.
SW. to NW.	30.20 and above and falling slowly.	Slowly rising temperature and fair for 2 days.
S. to SE.	30.10 to 30.20 and falling slowly.	Rain within 24 hours.
S. to SE.	30.10 to 30.20 and falling rapidly.	Wind increasing in force, with rain within 12 to 24 hours.
S. to SW.	30.00 or below and rising slowly.	Clearing within a few hours, and fair for several days.
S. to E.	29.80 or below and falling rapidly.	Severe storm imminent, followed, within 24 hours, by clearing, and in winter by colder.
SE. to NE.	30.10 to 30.20 and falling slowly.	Rain in 12 to 18 hours.
SE. to NE.	30.10 to 30.20 and falling rapidly.	Increasing wind, and rain within 12 hours.
SE. to NE.	30.00 or below and falling slowly.	Rain will continue 1 to 2 days.
SE. to NE.	30.00 or below and falling rapidly.	Rain, with high wind, followed, within 36 hours, by clearing, and in winter by colder.
E. to NE.	30.10 and above and falling slowly.	In summer, with light winds, rain may not fall for several days. In winter, rain within 24 hours.
E. to NE.	30.10 and above and falling rapidly.	In summer, rain probable within 12 to 24 hours. In winter, rain or snow, with increasing winds, will often set in when the barometer begins to fall and the wind sets in from the NE.
E. to N.	29.80 or below and falling rapidly.	Severe northeast gale and heavy precipitation; in winter, heavy snow, followed by a cold wave.
Going to W.	29.80 or below and rising rapidly.	Clearing and colder.

west of you; that when it is east the center is west; when it is south the center is north; when it is southwest the center is northeast, and when it is west or northwest the center is east of you.

Difference between Weight and Pressure of the Air. Air at sea level and at 32° temperature weighs one and one third ounces per cubic foot. A room twenty by twenty by ten feet contains some 333 pounds of air. The pressure of the air is a quite different thing. It is the sum of the weights of all the cubic feet of air that are stacked up, one on top of the other, clear to the top of the atmosphere. This is why the higher one goes, the less the pressure of the air, because there are a less number of cubic feet above. And then each cubic foot weighs a slight fraction less than the one just beneath it because the air has expanded. The room afore-mentioned sustains a pressure of 5880 on its floor and a like pressure on its ceiling, and a half of this pressure on each of the sides of the room. The room does not collapse because the air exerts a like pressure on the outside of the room and the two pressures are equal — one inward and the other outward.

The Principle of the Barometer. In 1643 some Florentine gardeners found that they could pump water only thirty-three feet high. This is because

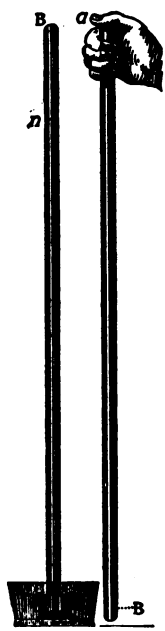


FIG. 7. — Mercurial Barometer. The glass tube on right is filled with mercury. With the thumb over the open end, it is reversed so that its open end rests under the surface in a basin of mercury on the left, and the mercury in the tube falls to *n*, at which point it is sustained by pressure of the air on surface of the mercury in the basin.

the entire volume of air, if it were compressed to the density of water, would equal a covering around the earth of that depth. When the gardeners first began to work the plungers in their pump up and down they did not get water; it was necessary for them first to pump out all the air in the pipe leading down to the water in the well; then the water rose into the vacuum thus created, and it rose to a height that just balanced the weight or pressure of the whole body of air that rests upon the earth. Now, if the atmosphere surrounding the earth could be reduced to the density of mercury it would equal a covering only thirty inches deep; this is why the mercury normally stands at thirty inches high in the vertical vacuum tube of the barometer. (Figure 7.) In the complete barometer a graduated scale is attached so as to measure the fluctuations in the height of the mercury. If one were to ascend in

a balloon it would be found that the mercury would steadily fall with increasing altitude, until at eighteen thousand feet one half of the atmosphere would be left below and the instrument would read only fifteen inches instead of thirty. In ascending to the top of the Washington Monument, 555 feet, the pressure of the air decreases over one half inch.

The barometer rises and falls with the passage of storms because wind movement displaces air and causes it to accumulate at some places and become deficient at others, but in order to compare barometers exposed at many different elevations with the view of determining the geographic position of storm centers — of cyclones and anti-cyclones — it is necessary to reduce all barometric readings to sea level.

Weather Records Turn the Scales of Justice. How trivial the incident that may change the whole course of a lifetime and lead to peace and happiness or to discord and sorrow! Likewise the parting of the clouds and the coming through of the sunshine, or the moment of the beginning of rainfall, or the amount of rain that falls within a given time, or the direction of the wind, or the velocity of the wind, or the temperature of the air, or the depth of the snowfall literally thousands of

times has furnished the evidence in courts of law that has turned the scales of justice in civil suits involving large sums of money, and in criminal cases where a prison sentence or the hangman's noose threatened the defendant.

For illustration let us say that a ship breaks from its mooring, crashes into another ship in the harbor and sinks it. If the force of the storm is no greater than has previously occurred in that harbor, the first ship is liable for the loss of the second ship. But if the automatically recording instruments of the Weather Bureau show that at that time the velocity of the wind was greater than ever had been known before, then the loss is due to " an act of God " and the ship that broke her mooring is not liable for damages to the ship that was sunk, provided proper provision was made for such velocity of wind as reasonably might be expected to occur with the passage of a storm.

To cite a case that actually occurred: A railroad company was sued for the loss of a million dollars' worth of lumber that was burned, as alleged, by sparks from one of its locomotives. Here came in the wind records of the Government and proved that at the time of the starting of the fire the wind was steadily and forcefully blowing in a direction

opposite to what would carry the sparks to the lumber, and the company was protected against an unjust verdict.

Again heavy rain fell in excess of the capacity of the sewers of a city to carry away the water, and private property was damaged by the flood. In this case the city was compelled to pay for the damage to property, because the records of the Weather Bureau showed that previous rainfalls had been of equal or greater amount in the same period of time, and the city should have constructed its sewers of sufficient capacity to carry away such precipitation as experience showed was liable to occur.

The writer was once an expert witness in what then was a famous case. The defendant, a young and handsome woman previously of unimpeachable character, was being sued for divorce. Two witnesses swore that they had seen her come to an open window, facing south, at seven o'clock in the morning, in a house in which she should not have been, stand for several minutes looking into the garden upon which the window faced, clad only in her night robe. Unfortunately the woman was not able to establish a satisfactory alibi for the morning in question, and she stood facing a terrible

calamity with no power to establish her innocence. Her accusers had given as a reason why she stood so long at the open window that the morning was warm and balmy. But, fortunately for the innocent woman, the weather records came to her defense when her case seemed hopeless and her life was about to be blighted with a scandal from which she never would be able to free herself, and proved that at the very time when she was supposed to have been standing in the open window a torrential rain was falling and a wind of fifty miles per hour was beating upon the outside of the window panes. The woman was acquitted and one of the witnesses spent several hundred balmy mornings behind prison bars.

At another time the writer came into a case where a robber had shot and killed a citizen who surprised him in the committing of his crime. The robber was on trial for murder and his lawyers were attempting to clear him by the introduction of evidence to prove that the day was so foggy that the State's witnesses had blundered and seized the wrong man when they chased the murderer around a corner. The weather expert destroyed the only evidence that tended to raise a doubt in the mind of the jury as to the man's guilt, by testifying that fog could come to the surface of the earth only when

the air was abnormally light and the wind calm or only gentle; while at the time of the murder the barometer was unusually high and the wind brisk. Here again the meteorological records aided in vindicating the right, and secured the conviction and execution of a brutal murderer.

A remarkable case was that in which a tramp was being tried for the murder of a miserly old woman who was believed to carry a large amount of money about her person. The tramp came to her door and asked for food. She took him in and fed him and soon thereafter he was seen hastily to leave the house. An hour after he had gone the woman was found murdered and her clothing rifled. The tramp was overtaken, found to have a large amount of money of small denominations in his pockets, indicted, and placed on trial. The principal witness for the State was a man who was repairing a frozen water pipe in a trench by the side of the house opposite to that by which the tramp entered and left. He saw the blow struck, ran in fear to his home, and then informed the police. In explaining how he came to see the criminal act, he testified that he climbed out of the trench to get a drink from a bucket standing near by, and as he raised the bucket his eye came in line with a window of the house, through

which he witnessed the murder. The case seemed clear against the tramp, as other witnesses had seen him enter and leave the house and positively recognized him. Just here his lawyer asked the trench digger how long the water bucket had been sitting by the side of the trench. The latter said it had been there from 7 o'clock until 10. Then the weather records came in to confound the falsifier and to vindicate innocence, for the automatic tracing of the pen that records every movement of the temperature proved that the temperature had not been above zero any time during the three hours that the bucket had been exposed and that it contained a solid chunk of ice if it contained anything. The trench digger then confessed that he himself was the murderer. He had seen the tramp enter and leave and thought it a favorable opportunity to commit the crime and put the evidence on another.

CHAPTER VII

FROST

THERE is nothing in the study of the atmosphere that so intimately concerns the horticulturist and the gardener as knowledge of the conditions under which frost forms, and the methods that may be pursued to gain immunity from its disastrous effects, or to lessen the loss.

Frost does not necessarily form from air that has fallen to the freezing point, as many suppose. On the contrary, the air ten feet or less above the vegetation may be several degrees above freezing when there is a heavy and destructive frost upon vegetation. The fact is that vegetation radiates heat towards a clear sky faster than does the air and may fall to the freezing point or below; while the air, except the molecules actually in contact with the vegetation, is considerably warmer. Frost is not frozen dew. The water vapor is precipitated, or

rather congealed, upon the vegetation without passing through the liquid state at all. Frost is spoken of as light, heavy, and killing. Tomato plants are killed by only a light touch of frost, while fruit blossoms will stand several degrees of cold below freezing. Therefore the tomato grower would consider as killing a frost that to the fruit grower would only appear as light.

The radiation of heat from the earth is continuous both day and night when there are no clouds to obstruct the passage of the heat rays. The amount received from the sun during the day is greater than the loss by radiation from the earth and the temperature of the air rises. After the setting of the sun the radiation of the earth goes on but there is no incoming heat from the sun to offset the loss and the temperature of the air falls. As previously stated, the soil and vegetation radiate faster than the air and the air in immediate contact with the soil is cooled by conduction to it. Thus over a level plain on a clear calm night there is found a relatively thin layer of cold air near the ground, which increases in temperature up to two hundred or three hundred feet, or which may be only five or ten feet deep. Over sloping ground the force of gravity tends to cause this thin surface layer of cold air to move

down the slope and to gather in depressions in somewhat the same manner as water would move. Such movement is called Air Drainage. Of course this air is slowly gaining heat by compression as it passes to lower levels, but it is hugging closely to the cold

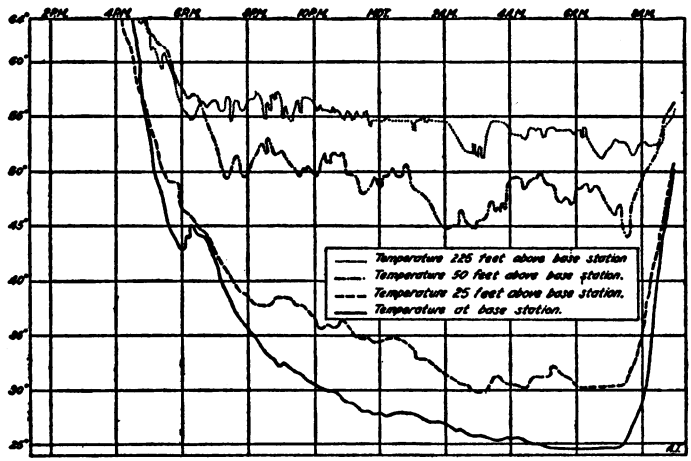

Temperature 225 feet above base station
Temperature 50 feet above base station.
Temperature 25 feet above base station.
Temperature at base station.

FIG. 8. — Continuous records of the temperature from 4 P.M. to 9 A.M. at the base and at different heights above the base of a steep hillside, showing the great differences in temperature that sometimes develop on a clear, still night. Although the temperature at the base was low enough to cause considerable damage to fruit, the lowest temperature 225 feet above on the slope was only 51°. Note that the duration of the lowest temperature was much shorter on the hillside than at the base. — *Weather Bureau.*

earth and losing by conduction much or all that it thus gains by compression.

After a study of the contour of the region with respect to air drainage the writer purchased a con-

siderable tract of land near Rockville, Montgomery County, Maryland, and planted extensive orchards thereon, with the result of harvesting nine successful crops of fruit in a period of ten years after the trees became large enough to bear. With the composition and the surface covering of the soil the same, the low places in a field are always the ones that suffer most when frost is possible. Figure 8 shows a minimum temperature of 25° to have occurred at the base of a steep hillside when on the higher ground at an elevation of but fifty feet the lowest temperature was 44°, and at two hundred and twenty-five feet up the mountainside the minimum was 52°.

In selecting a location for an orchard it is not so much a problem of elevation above sea level as elevation above the surrounding region. The direction in which the slope faces makes little difference. The prime consideration is to get sufficient air drainage to gain the greatest protection against frost without selecting land with such a steep slope as to furnish excessive soil drainage and which would be difficult to cultivate and move about upon in the spraying of trees and in the picking of fruit. In the Maryland orchard the elevation was only five hundred feet above sea level and only about two hundred feet above the surrounding region, and

the slope was so gradual as almost to be imperceptible to one passing over it.

After nightfall the air on mountain peaks and on hills and ridges soon becomes cooler than the air at the same elevation out over the open valley, due to contact with the elevated earth, which radiates heat and cools faster than the air.

Water vapor has a great capacity for heat. It is the most effective of the various gases present in the atmosphere in obstructing radiation of heat from the earth, as well as in absorbing incoming radiation from the sun. The night temperature, therefore, falls more slowly when the relative humidity is high than when it is low, that is to say, when the air is nearer saturation, or nearer its dew point. Drops of water that collect on the outside of a pitcher of ice water on a warm day are formed through the chilling of the air in contact with the pitcher; they begin to form as soon as the temperature of the pitcher reaches the dew point of the air, which temperature varies in accordance with the amount of water vapor present in the air at the time. After sundown the temperature of exposed objects falls, of some faster than others, depending on their capacities for radiation. Vegetation radiates freely and often falls to the dew point of the air, at which

time dew begins to form on it and continues to be deposited as long as the temperature remains above freezing. Now, here carefully note that if the dew point is above 32° the condensation of water vapor in the form of dew liberates latent heat, which usually will be sufficient to check the fall of temperature and prevent the formation of frost. If the dew point of the air is 32° or lower frost forms. If the dew point is very low the temperature may fall low enough to cause much damage without the formation of any frost. As an example, if the dew point be 20° and the temperature falls to 24° much damage might be done to growing crops and no frost appear. This phenomenon is called black frost; it seldom occurs. From the foregoing it might be assumed that the possibilities of frost might safely be forecast from an observation to determine the relative humidity taken early in the evening, but unfortunately experience has shown that reliance cannot be placed in such method of forecasting, as the humid air of early evening may be displaced by much drier air before the hour of minimum temperature the next morning.

One of the best locations to gain immunity from frost at the critical period of plant growth is immediately to the leeward of a considerable body of

water. Wind blowing from a large body of water is always heavily laden with moisture, which decreases the rate of radiation both day and night, but especially during the period of cold in the early morning when frost is liable to occur. Such winds, largely affected by the temperature of the water over which they have passed, modify the temperatures of both day and night.

The all-important condition for the formation of frost is an atmosphere already cool, with a gentle northwest wind and a clear sky, which condition, with more or less coolness, always accompanies the high barometric areas that follow the low-pressure areas of warmth, cloudiness, and moisture.

At an expense of two millions of dollars per annum the Government maintains some two hundred observation stations of the Weather Bureau, and twice daily telegraphs observations to all the large cities of the nation, but unfortunately in many cases these are not published for the benefit of the people who could make valuable use of them. The Bureau's own deductions from these observations, in the form of forecasts and warnings, are extremely valuable, but an even greater service could be rendered the public by neatly lithographing an evening weather map and mailing it from all large cities each

night, so that every intelligent person whose business is affected by the weather could, through a study of the chapter on Forecasting in this book, judge for himself as to the effect that the coming weather may have on his particular interests. One could then watch the movements of the high barometric areas and the low areas and become weatherwise himself, and he who studied these charts the most diligently would have an advantage over less progressive competitors.

Evaporation goes on at all temperatures, even below freezing and from solid ice, its rate, of course, being diminished by low temperatures. At times, in spring or fall, the temperature of the air over rivers, when there is little wind, falls so far below the temperature of the water that the water vapor rising from the river by evaporation is quickly condensed in the form of fog, which may cover a part or all of the low contiguous land, checking radiation and preventing a further fall in temperature.

In valleys near the ocean, fog sometimes drifts in from the water when frost is imminent and prevents its formation. On nights with fog, contrary to the usual condition, the hillsides are always colder than the lowlands, unless the fog extends high enough to cover them.

In 1891–1894 the writer, in studying the conditions under which frost forms on the cranberry bogs of Wisconsin, was impressed with the fact that the occurrence of frost on a given field depended as much on the character of the surface and its covering as it did on the temperature of the air a few feet above, one place receiving an injurious frost, another a light frost, and still another none at all, while each had the same conditions as to temperature, wind velocity and direction, and all were at the same elevation, so that the differences could not be accounted for by air drainage.

In one case the marsh was cleanly cultivated and covered with sand, in another there was clean cultivation but no sand, and in still another case there was a thick growth of vegetation. As the result of a long series of observations conducted by Professor H. J. Cox, working under the directions of the writer, minimum thermometers were placed among the vines over newly sanded surfaces in two marshes, one at Cranmoor and one at Mather, Wisconsin. The locations selected for this inquiry represented the best results that could be secured from sanding, draining, and cultivating. Comparison was made at each marsh between the readings taken close to the vines of the clean part of the marsh and

those taken close to the surface over the unsanded peat bog. The average lowest night temperature over the sand for the four months was 5.9° higher than over the peat at Cranmoor, and 4.2° at Mather. On one night the minimum over the surface at Cranmoor was 12° higher than over the peat, while at Mather a difference of nine degrees was recorded on another night.

Through cultivation the marsh may be kept free from weeds, moss, or other rank growth, thus permitting the sun's rays to reach the soil and increase its temperature during the day, while a growth of thick vegetation screens the soil from the sun's rays, and there is consequently less heat in the latter soil to be given out during the hours of low temperature at night. Drainage lowers the specific heat of the soil and decreases the cooling effect of evaporation. Therefore, under sunshine, the dry soil becomes warmer than the wet and, whether or not it has a greater quantity of heat to give off at night, it has a higher temperature and therefore radiates more freely to the air above. A covering of sand likewise lowers the specific heat of the surface and thereby causes it to gain a higher temperature during the day than an unsanded surface receiving the same solar rays. It therefore radiates more rapidly at the critical time

when heat is needed to prevent the temperature of vegetation from falling to the freezing point and gaining a deposit of frost.

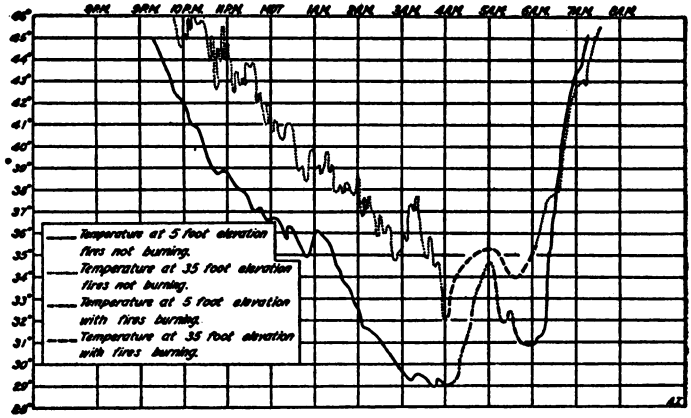


FIG. 9. — Continuous records of the temperature 5 feet and 35 feet above ground on a tower in a pear orchard. Note the large difference in temperature at the two levels before the orchard heaters were lighted at 4 A.M. By 5 A.M. the temperature was practically the same at the two levels, showing that the heat from the burning oil had been nearly all expended in raising the temperature of the air within 35 feet of the ground. This point is further illustrated by the fact that at 5 A.M. when most of the heaters were extinguished, the temperature at the 5-foot level fell rapidly, while it remained practically stationary at the 35-foot level. — *Weather Bureau.*

In many orchards in the Rocky Mountain States, where fruit growing is highly profitable and the injury from frost more than probable every year, an extensive use is made of oil and other fuel-burning heaters between the rows of trees. Those who wish further information with regard to this matter

should send to the Weather Bureau, Washington, D. C., for Farmers' Bulletin No. 1096. At first thought it would seem that heat so applied would be blown away or instantly escape upward. But on frosty nights there is not much wind; if there is, there is little danger from frost. And then, as

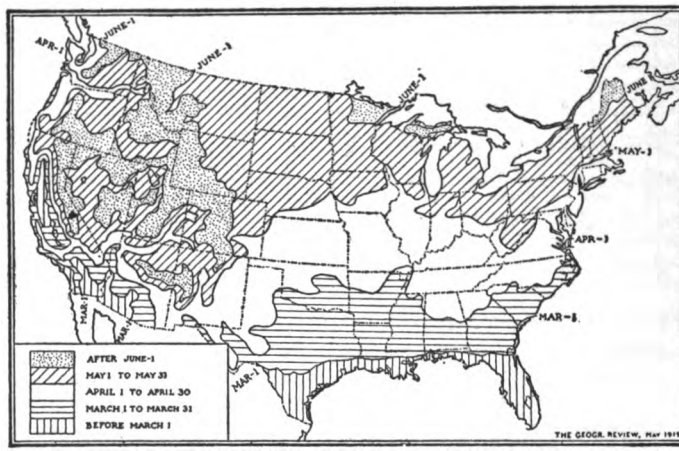


FIG. 10. — Average dates of last killing frost in spring.

previously stated, on such nights there is what is called temperature inversion, and the temperature actually rises with the first few feet of ascent, and the heated air soon reaches air of its own temperature, when no further ascent occurs. When the air forty feet from the ground is ten degrees warmer than it is around and in contact with vegetation, as often occurs on frosty nights, the heat from the

fires is nearly all expended in raising the temperature of the air within this forty feet. Figure 9 furnishes the result of an experiment illustrating the correctness of the foregoing theory.

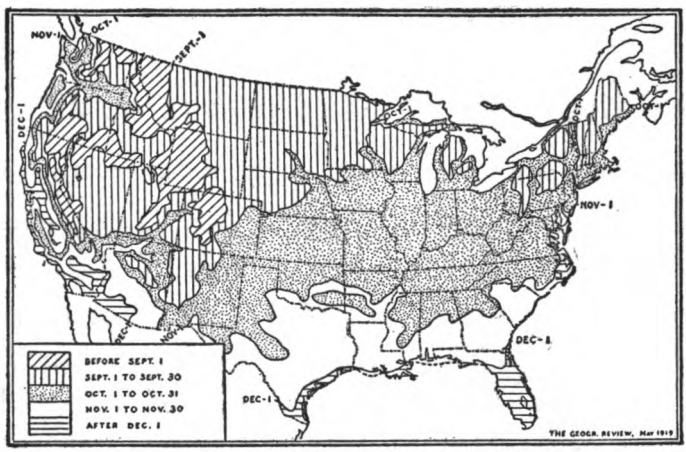


FIG. 11. — Average dates of first killing frost in fall.

Figures 10 and 11 show the average dates of the last killing frost in spring, and of the first killing frost in fall.

CHAPTER VIII

WIND AND PRESSURE OF THE GLOBE

CAUSE OF LOCAL WINDS AND OF GENERAL CIRCULATION

General Circulation. Differences in temperature, changing the specific gravity of the air, are the cause of the general circulation of the atmosphere about the earth, modified by the rotation of the earth; likewise the local circulation between land and water is caused by the different quantities of heat radiated by the two widely differing forms of matter, each attaining to a different temperature under the influence of the same solar radiation; and the inflow of winds to the cyclone and the outflow from the anti-cyclone are due to the same forces that cause the general and the local circulations.

If there were no difference in temperature between the equator and the poles the atmosphere would soon adjust itself in accordance with the laws of gravity, modified by the centrifugal force developed from the rotation of the earth, and the atmosphere for-

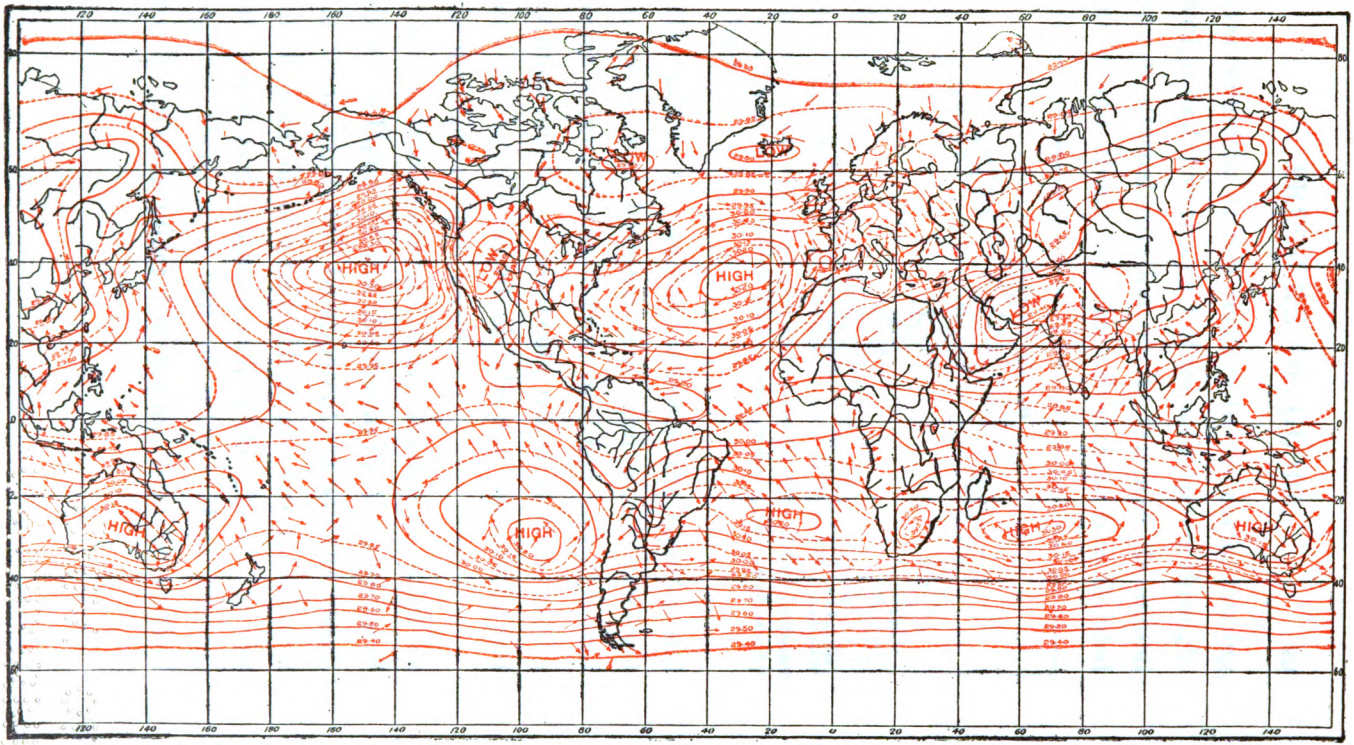


CHART 1. — HIGH AND LOW CENTERS OF ACTION AND PREVAILING WINDS OF THE GLOBE FOR JULY (Buchan).

ever would be at rest relative to the earth, moving with it as if it were a part of the solid sphere throughout its diurnal rotation on its axis and its annual movement about the sun. But there is a decided

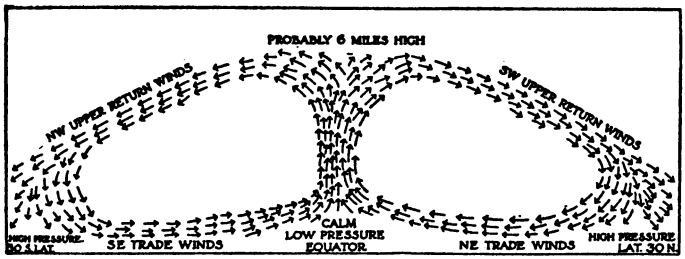


FIG. 12. — Trade wind circulation and reason for belts of high pressure at latitudes 30° N. and S. that extend around globe as shown by Figure 13.

difference in temperature between the equator and the poles and between land and water surfaces; hence a general circulation, modified and distorted by numerous local movements, which, in turn, may be modified by the height of hills and mountains and the direction of their trend.

Let us trace a current of air through its course as shown in Figure 12 and the reason for the blowing of the trade winds will be apparent, as will the reason for the location of a belt of high pressure at latitudes 30° north and south encircling the globe. At the equator there is a belt of calms. Here the air gently ascends under the intense heat of vertical

sunshine. It is humid, for there is much water surface in the region of the equator, and the air carries vast quantities of water vapor aloft, later to be precipitated as torrential rains in the Tropical Zone, as the air cools by expansion in its ascent. This air expands or bulges upward and overflows aloft northward and southward, causing low air pressure at the equator, because of the quantity of air moved to other latitudes, which more than compensates for the amount banked up over the equator by the centrifugal force of the earth's rotation.

Since air, passing away from the equator, must pass successively over parallels of latitude having less easterly velocity than that with which it started its journey, it runs ahead of the earth, and, relative to the surface of the earth, has a direction from the southwest north of the equator, and from the northwest south of the equator. Our current was divided at an altitude probably of six miles above the equator, one half following the northern and the other half the southern circuit. It was cooled by elevation and by radiation outward to space and as a result gained in weight and gradually descended, reaching the earth at about latitudes 30° north and south, and causing an accumulation of air at those

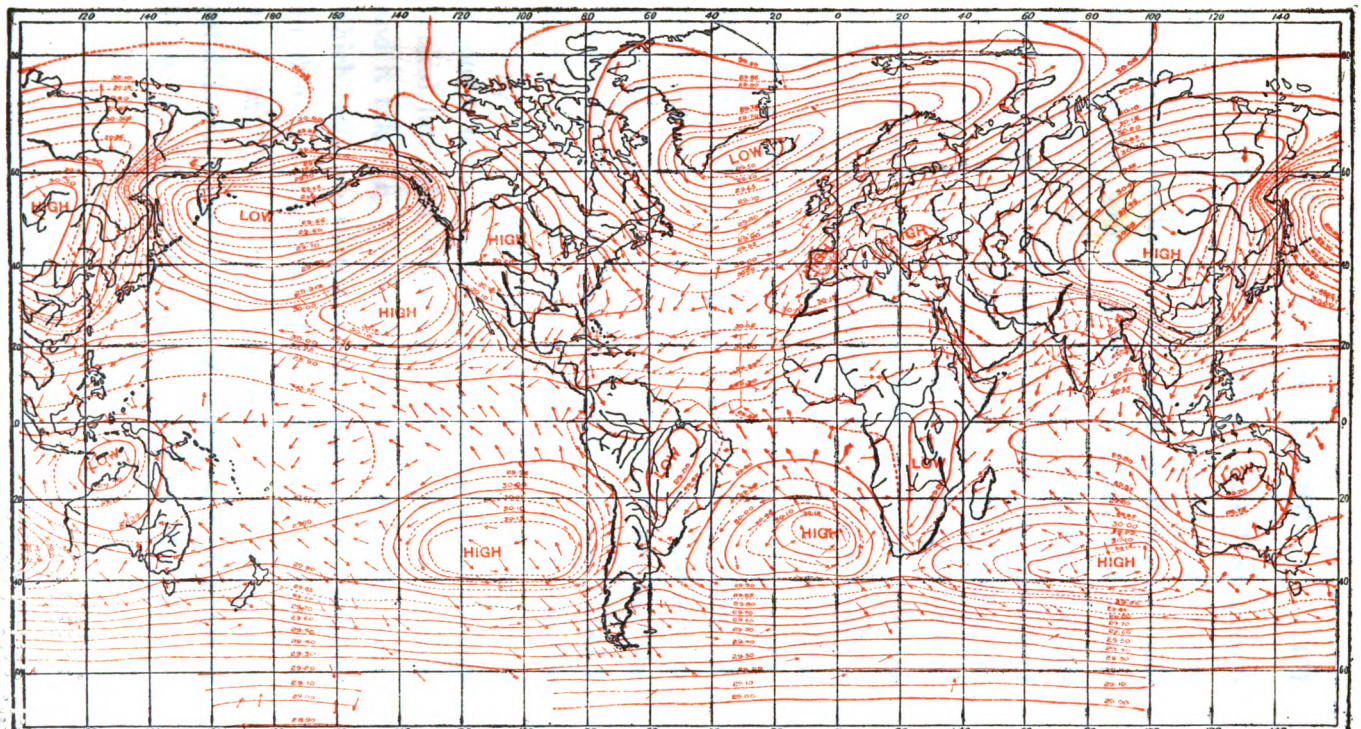


CHART 2.—HIGH AND LOW CENTERS OF ACTION AND PREVAILING WINDS OF THE GLOBE FOR JANUARY (Buchan).

latitudes and the belt of high pressure that irregularly surrounds the earth. In descending in the belt the air breaks up into a number of anti-cyclonic systems, sub-permanent highs or Centers of Action, which have so much to do with initiating the migratory Highs and Lows that create the weather of the earth, as will be fully explained in the Chapter on Weather Forecasting. The intensity of these centers of action is modified and their geographic positions shifted with change of season. (See Charts 1 and 2.)

Trade Winds. But to return to the current that we left as it divided above the equator (Figure 12) and descended on an inclined plane to latitudes 30° north and south. It is cooler and dryer and heavier than when it started to ascend and it has lost the thousand miles per hour and more easterly velocity that it had at the equator and now only has the velocity that belongs to latitude 30°; therefore as it moves toward the equator from either side it lags behind latitudes whose easterly velocity is greater, and it takes up a direction partly toward the west, which, relative to the earth, makes it a northeast wind in the Northern Hemisphere and a southeast wind in the Southern Hemisphere. And thus is established a circulation the lower part of which is known as the "trade winds." (Figure 13.)

Navigators profit largely by availing themselves of the west winds in the middle latitudes and of the east winds in the tropics. To the daring and per-

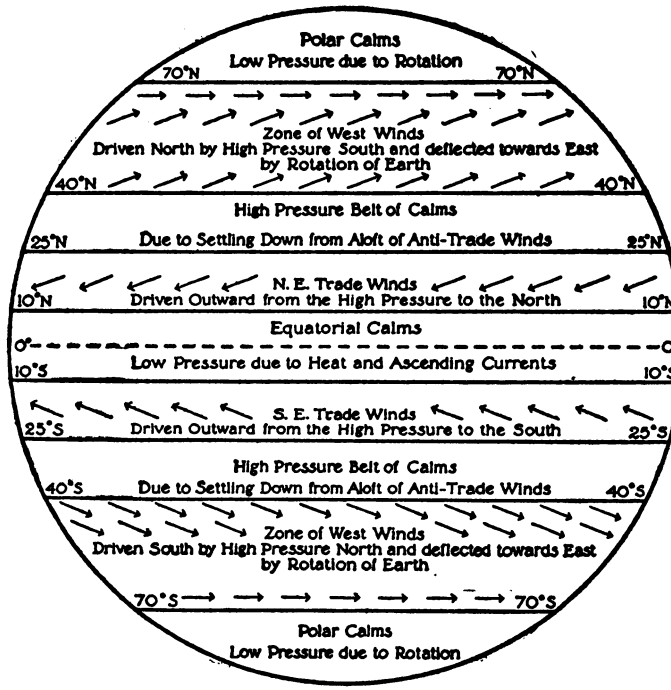


FIG. 13. — Average surface winds and pressure of the globe.

sistence of Columbus, and the force and constancy of the trade winds which blew him westward, we owe the discovery of America.

Winds of Middle Latitudes. Now study Figure 12 and associate the information it conveys with

that of Figure 13, and observe that from the two belts of high pressure the air is pushed outward on both sides. In each case it starts as a true north or south wind, but, due to the rotation of the earth, is always and everywhere deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere, and this deflection increases until what started as a poleward wind in the middle latitudes soon becomes almost a due west wind. In this region of west winds cyclonic storms are more frequent than in any other part of the globe. Now get clear in the mind the fact that no matter what may be the direction of the wind inside a cyclonic or anti-cyclonic whirl (often one thousand miles in diameter), the whirl is carried toward the east by the general drift from the west of the winds between latitudes 30° and 60°, and toward the west in the region of the trade winds.

Low Barometer at the Poles. Even though the air is contracted and rendered denser by the great cold of the Arctic regions, the pressure remains low because of the quantity of air driven equatorward by the centrifugal force both of the earth and of the winds themselves as they run ahead of the earth and encircle the globe in the middle latitudes.

Data too Meager to Show Full Circulation Aloft of the Atmosphere of the Globe. Many charts

have been published in the attempt to show how the atmosphere circulates below and aloft through the whole world. They only have speculative value, as our knowledge is too limited to permit us to unravel the complexities of all the upper movements.

Rain Winds of the Tropics. The trade winds, mostly moving over water surfaces, are laden with moisture, but, gaining temperature as they move towards the equator, their capacity to hold water vapor steadily increases, and therefore they do not become rain winds unless forced to ascend by the interposition of mountains, or until cooled by ascension at the equator. In no part of the world does the air rise so steadily and in such great volume as in the equatorial belt of calms and low pressure. Hence this is the region of greatest rainfall. During the two rainy seasons, spring and fall, the day opens clear; near midday the clouds gather and rain falls early in the afternoon; after which it quickly clears. This is so regular a program that one lays his plans accordingly. There is almost no rain in December and January; this is because the belt of calms and the inflowing trade winds move northward and southward with the migrations of the sun, and in December and January, the sun being far south, the northern trades, with their rain-

less winds, cover the equator and the region formerly occupied by the belt of calms. In midsummer the sun is far north and then the southern trades move up and give dryness to the equator. In the northern trades, of the moderate amount of rain that falls, the greater quantity falls in summer; in the southern trades the order is reversed.

Rain of the High-Pressure Belts and of the Regions of West Winds. In the high-pressure belts the air is settling down and gaining heat by compression and there is not much horizontal movement. These are, therefore, regions of but little rainfall, and all the great deserts occur in or near them. The belts of west winds are the regions of most frequent cyclonic activities. Here the rainfall is quite equally distributed throughout the year and is the result of the mixing of the air by storms and its cooling by expansion as it is carried upward in the migrating whirl.

Circulation between Continents and Oceans. In Chapter X, under the sub-caption "Influence of Continents and Oceans on Climate", the circulation between them is well explained. In general the movement is from the continent to the oceans in winter, with the air flowing inward aloft to settle down and take the place of that which passes out to sea. In summer the directions are reversed.

Daily Variation in Coastal Winds. In summer, when there are no forceful storm winds blowing steadily from one direction for several hours at a time, there will daily spring up gentle to fresh winds from the surface of oceans and large lakes to the land, because of the influence of the sun's rays in heating the land to a higher temperature than it does the water. These winds will not appear on cloudy days and they will extend inland but a few miles.

Monsoon Winds. During winter the vast continent of Eurasia (Europe and Asia) cools to such an extremely low temperature as to develop a High, or center of action, of great energy and extent, which drives a steady dry monsoon into the Indian Ocean and China Sea. Unlike the trade winds, these winds reverse their direction in the summer; then the intense heat of the continent to the north develops an extensive Low, which draws the ocean winds inland and extends its influence so far south as to attract the southeast trade winds of the Southern Hemisphere and, turning them so that they flow from the southwest, continue them far into the interior of Asia. Since the summer monsoon blows from a tropical sea it comes heavily laden with water vapor and as it rises over the mountains of the great Himalayan system copious rains are

precipitated. In Australia, Africa, South America, and some parts of the North American continent monsoon influence in various degrees is felt, but in no place is the monsoon so important as in the countries bordering the Indian Ocean. (Charts 15 and 16.)

Föhn Winds. This is a hot wind that sometimes blows down a mountain side in the Alps. In the Rocky Mountains it is called the Chinook Wind. It is caused by moisture-laden air being drawn over a high mountain so quickly that the heat liberated in condensation does not have time to escape by radiation. The air cools by expansion as it ascends on the west side of the mountain, but it gains this all back by compression as it descends, and it has added to its temperature much of the heat of condensation. It is dry and greedily evaporates snow from the ground in winter, clearing off a deep covering within a few hours.

How Winds Are Deflected by Earth's Rotation. Every free-moving thing, whether wind or projectile, is deflected to the right of its initial direction by the rotation of the earth in the Northern Hemisphere and to the left in the Southern Hemisphere, unless the object be moving exactly along the line of the equator. Winds moving inward to a Low are therefore so deflected as to cause the cyclone to

gyrate in a direction contrary to the movements of the hands of a watch. In an anti-cyclone the movement is with the watch. In the Southern Hemisphere these wind directions are reversed.

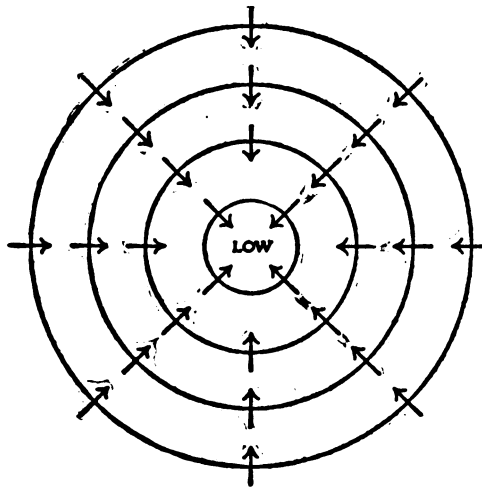


FIG. 14. — How winds would blow into a cyclone on a non-rotating earth.

Figure 14 gives an illustration of what would be the movement of air inward to a cyclone on a non-rotating earth. The winds would blow along radial lines for a time, but, converging together as they began to ascend, they doubtless would soon set up a gyration about the center. On a non-rotating earth this gyration would be clockwise as often as it would be anti-clockwise, but on a rotating earth the gyration can be in but one direction. (Figure 15.) Even tornadoes, whose diameters of rotation are never but a few hundred feet, obey this law. In little dust whirls, in which the movements of air may be comprehended from the mo-

tion of the trash that is whirled about and which are tornadoes in miniature, the direction of gyration may be either way. They are too small for the deflecting force to be appreciable, and it may be that the tornado is forced to take its direction of gyration from the cyclone in whose southeast quarter it has its origin.

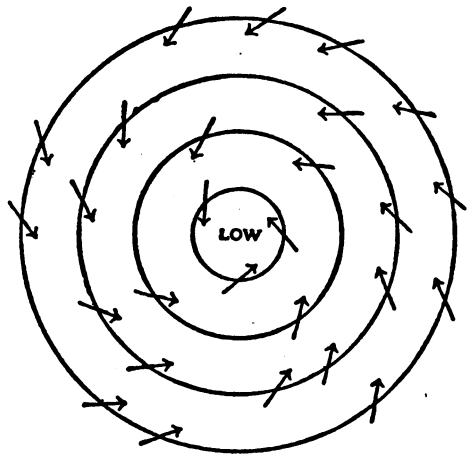


FIG. 15.—Deflection of wind due to earth's rotation.

How Wind Velocity Increases with Altitude. Figure 16 shows how the velocity of the wind increases with elevation in the free air up to five thousand meters (about three miles). The average for the year, for the summer and for the winter, is given. It increases most rapidly up to six hundred meters in summer and up to eight hundred meters in winter. From these two heights there is a steady and pronounced slowing down of the wind up to one thousand meters; after which it increases up to

five thousand meters, and how far beyond we know not. In winter there is a singular acceleration of

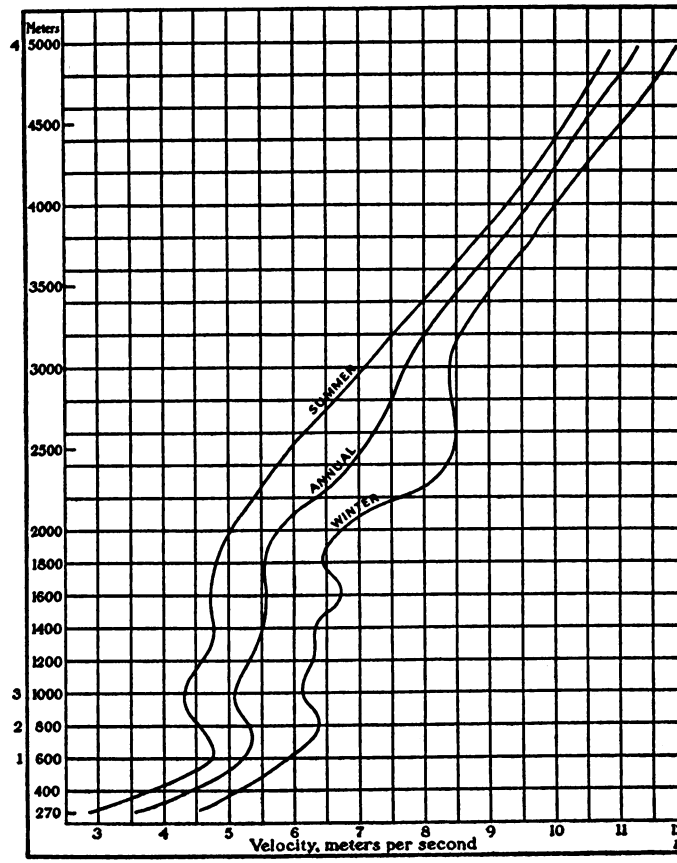


FIG. 16. — Annual, summer, and winter wind velocities, with altitude. 1, 1850 feet; 2, 2467 feet; 3, 3083 feet; 4, 15,417 feet.

velocity in the stratum between two thousand and twenty-five hundred meters and then no increase for

the next five hundred meters; after which there is a uniform and steady gain up to five thousand meters. Starting at two hundred and seventy meters, the average velocity for the year is 3½ meters per second, or about 7¼ miles per hour. At five thousand meters altitude the average for the year is 11¼ meters per second, or about 27 miles per hour.

CHAPTER IX

HOW TO FORECAST FROM THE DAILY WEATHER MAP

IT IS NOT DIFFICULT TO BECOME WEATHERWISE AND THEREBY TO GAIN ADVANTAGES IN HEALTH, HAPPINESS, AND BUSINESS

THE person who will take the time to learn to interpret the daily weather map has a decided advantage over those who are less progressive. The maps may be secured by applying to any Weather Bureau station. Many members of commercial associations, having the advantage of seeing the large glass weather map that is made each morning by an observer of the Weather Bureau and displayed on the floor of the association, have become expert weather forecasters. The value of the principal crops of the country is largely influenced by the weather, as are the prices of transportation and industrial stock; and there is hardly a business that directly or indirectly is not influenced by the prospects of coming weather.

Vessel masters, long accustomed to forecast the near approach of storms from the action of their "glass" (barometer), now have learned that the daily weather map shows them at a glance the height of not one but of many barometers scattered over a wide area and read at the same moment of time. They see that the direction and the force of the wind are the results of differences in air pressure; that the air flows from a region where the air pressure is great, that is to say, where the barometers are high, towards a region where the pressure is less, or where the barometers are low; and that the velocity of the wind will be in proportion to the difference in the pressure of the air. Coastwise and lake shipping are therefore not only affected by the forecasts made by the Weather Bureau but by the forecast made by the masters themselves when they can get access to the daily weather map. Their own lives and the lives and property of others are in their keeping. But the great mass of intelligent people have no idea of the methods employed in the making of the weather map and of the many and widely diversified uses to which a study of its data would lead.

One first must learn of the simple manner in which the map is constructed; then, by a comparison of

the map each day with the preceding chart, he soon will be able to detect the beginning of storms, trace them through their various migrations as they cross the continent and finally pass out to sea, bidding them bon voyage as they go in quest of a more eastern continent on which to bestow their blessings of rain and active, purified air; or, as it often may happen, shuddering for the fate of the mariner who is caught in their fierce vortical whirls, and for the land areas that may be laid waste by their gyrating force.

How the Weather Map Is Made. At 8 A.M. to-day Washington time, which, by the way, is about seven o'clock at Chicago, six at Denver, and five at San Francisco, the observers at some two hundred stations in the United States and contiguous territory were taking their observations and from carefully standardized instruments noting the conditions of the atmosphere. By 8:20 A.M. the barometers at each station have been reduced to sea level, that is to say, they have been made to read what they would if they were located at the level of the ocean. Thus differences in air pressure that are due to differences in elevation are eliminated, so that they may not obscure those due to storm conditions. Then, for purposes of brevity and accuracy, the observations are reduced to cipher form,

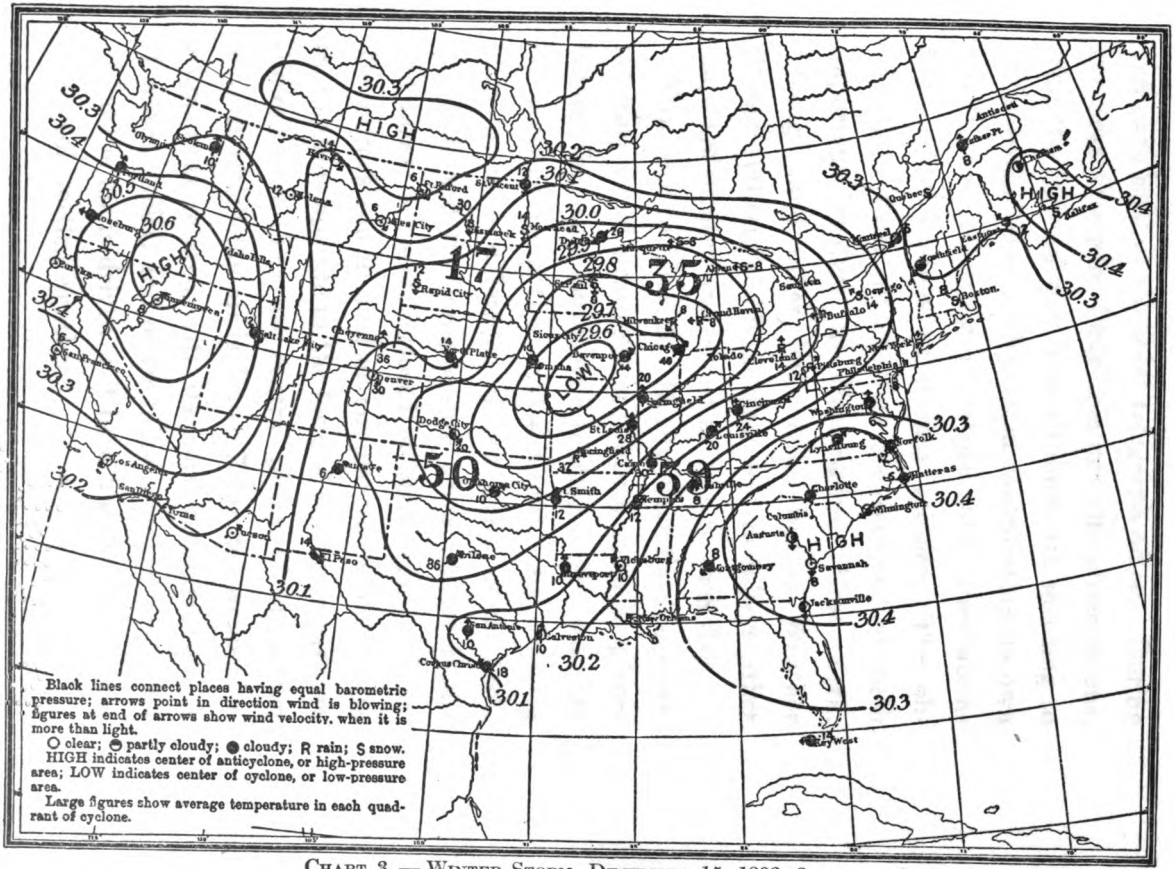


CHART 3. — WINTER STORM, DECEMBER 15, 1893, 8 A.M.

and each filed at the local telegraph office. During the next thirty or forty minutes the observations, with the right of way over all lines, are speeding to their destinations, each station contributing its own report, and receiving in return such observations from other stations as it may require. The observations from all stations are received at such important centers as Washington, New York, Chicago, and other large cities having Weather Bureau stations, and from these centers daily weather maps are printed and issued at 11 A.M. each day.

Now turn to Chart 3. Heavy black lines (isobars, meaning equal pressure) are drawn through places having the same barometric reading. The readings are omitted from the printed Chart. By drawing lines for each difference of one tenth of an inch, the high and the low-pressure areas (called Highs and Lows) are soon inclosed in their proper circles. These lines run in oval or circular form, indicating that storms operate in the form of great atmospheric eddies; that there are central places of attraction *towards* which the air is drawn if the disturbance be a low-pressure area, with its usual accompaniments of warm, moist, and often rainy weather, and *from* which the air is driven if it be a high-pressure area, with cool, settled weather.

The word "High" is written inside the isobar marked 30.6, located in southern Oregon, and the same word is written inside the isobar marked 30.4, located on the South Atlantic coast, and also inside the isobar 30.04, which traverses Nova Scotia. These are the regions of great air pressure. The word "Low" is written at the center of the area inclosed by the isobar 29.6, which is situated in the State of Iowa. The latter is the region of least pressure. Sometimes there are several such regions shown on the weather map.

Why the Wind Blows. Under the pull of gravity the atmosphere presses downward and outward, thus causing it to flow from the several regions of great pressure towards regions of less pressure. Observe the arrows, which fly with the wind, and it will be seen how generally this law is obeyed. The velocity with which the wind moves from the High toward the Low depends on differences in air pressure, modified in the lower stratum by the friction offered in passing over surfaces of varying degrees of roughness, the speed being greater over a water surface with the same difference in air pressure than over a level unwooded prairie, and greater over the open prairie than over an irregular wooded area. To illustrate:

If the barometer were 30.5 at Bismark, Dakota,

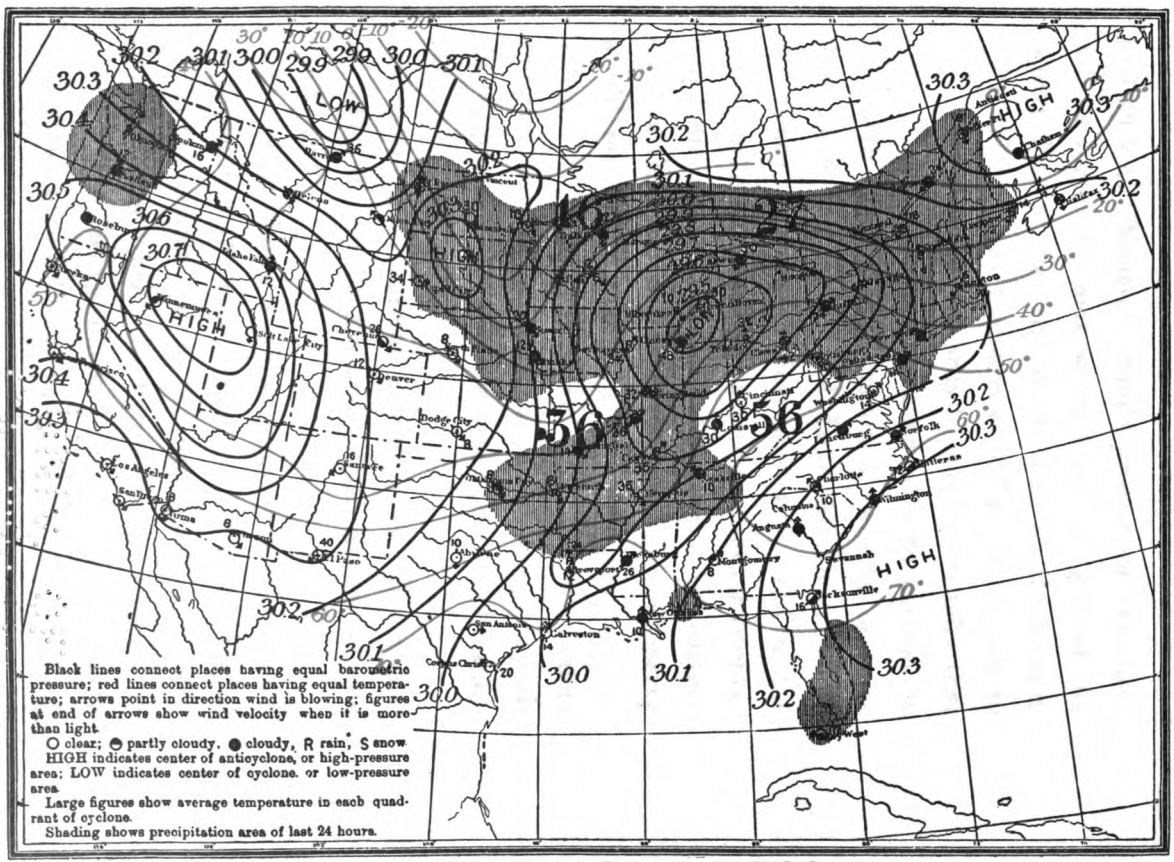
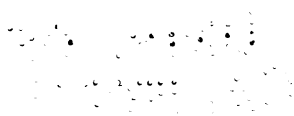

LOW
HIGH
HIGH
HIGH
Black lines connect places having equal barometric pressure; red lines connect places having equal temperature; arrows point in direction wind is blowing; figures at end of arrows show wind velocity when it is more than light.
○ clear; ◓ partly cloudy, ● cloudy, R rain, S snow.
HIGH indicates center of anticyclone, or high-pressure area; LOW indicates center of cyclone, or low-pressure area.
Large figures show average temperature in each quadrant of cyclone.
Shading shows precipitation area of last 24 hours.

CHART 4. — WINTER STORM, DECEMBER 15, 1893, 8 P.M.



and 29.5 at Chicago, it would press upon the earth with a force of about seventy pounds greater per square foot at the first place than at the second. This difference in pressure would cause the air to flow from Bismark towards Chicago so rapidly that after allowing for the resistance due to friction on the earth there would remain a velocity of some fifty miles per hour, and Lake Michigan would experience a severe "Northwester"; and if the wind continued from the same direction for twenty-four hours a mighty sea would beat upon the eastern shore of the lake, and mariners and marine property would be at the mercy of a destructive tempest unless the Weather Bureau forecaster were alert and gave warning as soon as he saw such a juxtaposition of pressure distribution in the process of formation.

We will give careful attention to this chart, for when its details are understood, others will be easily read.

The chart shows a winter storm central in Iowa on December 15, 1893. The word "Low" marks the storm center. It is the one place in all the United States where the barometer reading is the lowest. The heavy black lines, oval and nearly concentric, about the Low, show the gradation of

air pressure as it increases quite uniformly in all directions from the center of the storm outward.

The arrows fly with the wind, and, as will be seen, almost without exception are moving towards the Low, or storm center, clearly demonstrating the effect of gravity in causing the air to flow from the several regions marked " High ", where the air is abnormally heavy, toward the Low, where the air is lighter. As the velocity of water flowing down an inclined plane depends both upon the slope of the plane and the roughness of its surface, so the velocity of the wind, as it flows along the surface of the earth towards the storm center, depends on the amount of the depression of the barometer at the center and the resistance offered by surfaces of varying degrees of roughness.

Storms and Cold Waves Simply Great Eddies in the Atmosphere. Now picture in your mind that all the air inside the 30.2 isobar, as it flows inward, is rotating about the Low in a direction contrary to the movements of the hands of a watch, and you have a fair conception of an immense atmospheric eddy. Have you ever watched the placid waters of a deep-flowing brook and observed that where the waters encountered a projecting rock little eddies formed and went spinning down the stream? Well, our storms are somewhat similar eddies in the atmos-

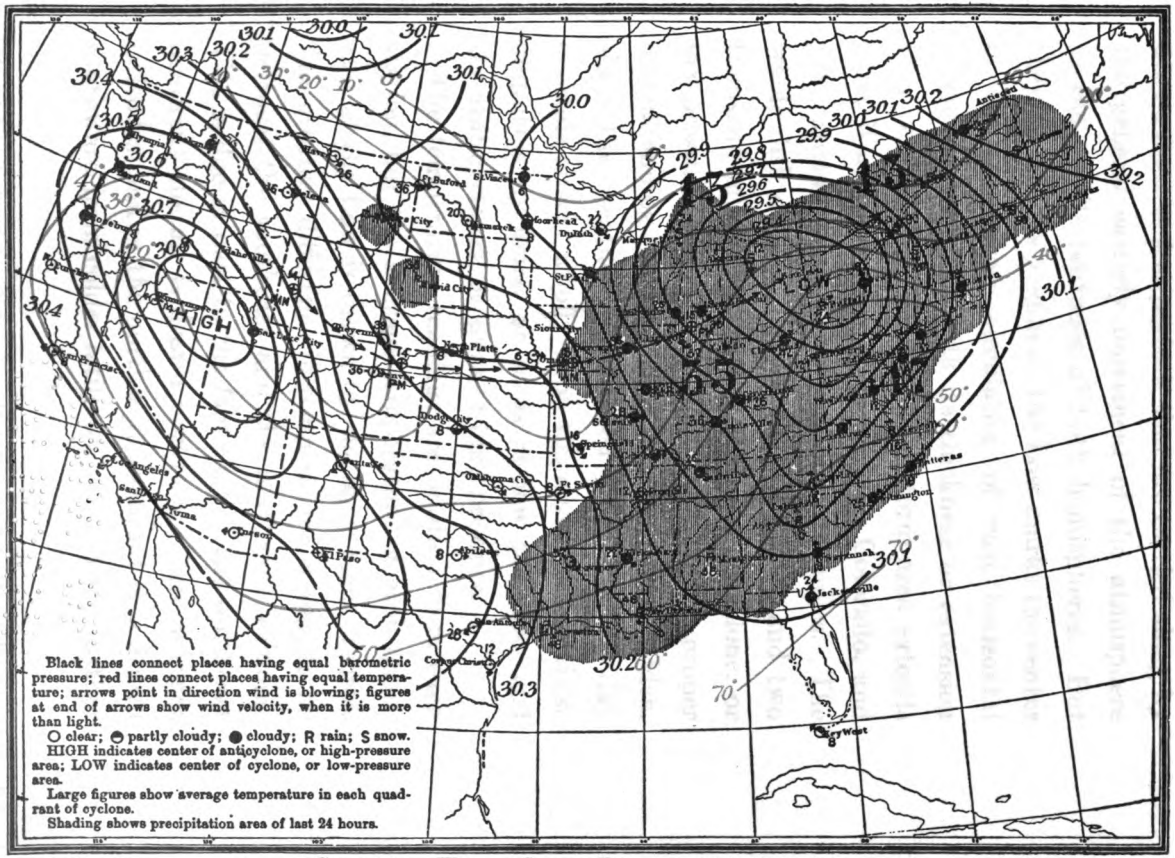
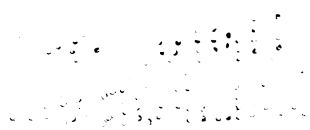

HIGH
LOW
Black lines connect places having equal barometric pressure; red lines connect places having equal temperature; arrows point in direction wind is blowing; figures at end of arrows show wind velocity, when it is more than light.
○ clear; ◔ partly cloudy; ● cloudy; R rain; S snow.
HIGH indicates center of anticyclone, or high-pressure area; LOW indicates center of cyclone, or low-pressure area.
Large figures show average temperature in each quadrant of cyclone.
Shading shows precipitation area of last 24 hours.

CHART 5. — WINTER STORM, DECEMBER 16, 1893, 8 A.M.



phere, more or less perfect, that are carried along by the general easterly movement of the atmosphere in the middle latitudes of both hemispheres. But they are not deep eddies; the Low marks the center of an atmospheric circulation of vast horizontal extent as compared with its thickness or extension in a vertical direction. Thus a storm area extends from Washington, D. C., to Denver, Colorado, and yet extends upward only about six miles. The whole disk of whirling air, six miles thick and two thousand miles in diameter, is called a cyclone, or low-pressure area. It is important that a proper understanding be had of this fundamental idea, since the weather experienced from day to day depends almost wholly upon the movement of these migrating cyclones, or areas of low pressure, and the anti-cyclones, or areas of high pressure.

The temperature readings are omitted from each station, but the average temperature of each quadrant of the Low is shown by the large black figures. The greatest difference in temperature is seen to be between the southeast and the northwest sections. This is due in part to the fact that in the southeast quadrant the air is drawn northward from warmer latitudes, and in the northwest quadrant it is drawn southward from colder latitudes, and to the further

fact that winds blowing into the west side of a Low have a downward component of motion, and those blowing in on the front, or east side, have an upward component.

One should gain a clear idea of the difference between the movements of the air in the cyclone and the movement of the cyclone itself, or its translation from place to place; how the wind must blow into the front of the storm in a direction partly or wholly contrary to the movement of the storm itself, and into the rear of the storm as it passes away; how the wind increases in velocity as it spirally gyrates about the center and approaches nearer and nearer the region where it must ascend; how the higher layers of air move spirally away from the center and thus cause an accumulation of air about and over the outer periphery of the Low, which in turn presses downward and impels the surface air inward. This whole complex system of motion moves eastward. Think of the sun drifting in space, while at the same time each of the planets maintains its respective orbit, and it will help one to visualize the phenomena of a migrating cyclone or anti-cyclone.

Chart 4, constructed from observations taken twelve hours later, shows that the Low has moved from central Iowa since 8 A.M., and is now, at 8 P.M.,

central over the southern point of Lake Michigan. The shaded portion of the chart shows that rain has fallen during the past twelve hours throughout nearly the entire region covered by the cyclone. This was due to the mixing of the air as the storm progressed, to the cooling by expansion as the air ascended, to the more rapid rotation about the storm center, because of the further lowering of the barometer at the center of the disturbance since the preceding chart was made, and especially to the more humid air encountered as the storm moved eastward and came nearer to the supply of moist winds, — the Atlantic Ocean.

On Chart 5 a line of arrows extends from the storm center westward to Wyoming, where the storm originated. A small cross inclosed by a circle marks its western extremity. Another cross located near Cheyenne shows where the storm center was located twelve hours after its origin. A third cross gives it location near Des Moines twenty-four hours after it started eastward. It was here that we began the study of this storm on Chart 3. A cross near Chicago indicates the distance traveled by the center during the third twelve hours, and Chart 5 shows its progress during the fourth twelve-hour period. When the storm was central at Cheyenne

the danger warnings for mariners were displayed at all ports of the Great Lakes, as the forecaster knew that in accordance with general laws the storm must move toward the east. When it was centered at Chicago, danger warnings were displayed on the Atlantic coast from North Carolina to Maine, as it was known that long before the storm reached the ocean the in-rush of wind toward the storm center would cause a dangerous on-shore gale and the breaking of heavy seas on the shore line. All craft that could be reached with the danger signals made safe in port, except the great ocean liners, which are of such strength as to safely withstand almost any storm. A special set of observations ordered by the Washington office of the Weather Bureau from its stations in the region of the storm, and well in advance of it, kept the chief forecaster informed as to the progress of the cyclone, and before the storm center reached the coast the danger signals communicated to mariners the fact that the winds would soon shift to northwest as the center of the disturbance passed out to sea.

The reader's attention will now be directed to the red lines on Chart 5; they pass through places having the same temperature, but for simplicity the readings of temperature, whereby these lines were

located, are omitted from the printed chart. Observe the line marked 40°; it passes across southern New England to western New York, but when it reaches the center of the storm it encounters the cold northwest winds blowing into the storm on its west side and is forced southward to Texas.

Charts 3, 4, and 5 give a graphic history of one severe winter storm. In summer such general storms do not often occur. They are frequent in spring and fall, but of higher temperature and less severity than in winter. In summer Lows drift sluggishly across the continent; the barometer at the center of the cyclone is usually not more than two to four tenths of an inch below the pressure of the Highs, and the rain, instead of falling in a broad sheet, as shown by the shading of charts 4 and 5, falls in numerous sporadic outbursts, each of which is but a few square miles in area, their combined surfaces usually covering only a part of the region over which passes the Low.

Cold Waves and the Speed of Storm Movement. Highs and Lows drift across the continent from the west towards the east at the average rate of about six hundred miles per day, or about thirty-seven miles per hour in winter and twenty-two miles in summer, the first at about the rate of an express

train, and the second approximating the speed of a freight. The Highs are attended by dry, cool, and settled weather. By a vortical action at their centers they draw down the cold air from great altitudes above the clouds. In winter, when vortical action is vigorous, they may reach upward to an altitude of seven miles. Air starting downward from this region has a temperature of some 70° below zero. We know this from the records secured by sending aloft free balloons carrying automatic thermometers. (Chapters II and III.) This air heats by compression because in its downward movement it is continually leaving more and more air above it to exercise pressure upon it. It gains about twenty degrees with each mile of descent, and if there were no other factors to the problem it would be hot air when it reached the surface of the earth instead of cold air. But early in its descent it gains such heat as to melt and evaporate the ice spiculæ floating at the height of the fleecy cirrus clouds; then it evaporates and clears away the moist clouds lower down and finally creates such *diathermancy* (the capacity to transmit heat without absorption; see Chapter V) that the heat lost by radiation to a clear sky causes what we call a "cold wave", and this notwithstanding the heat of compression.

The forecaster first observes a cold wave in the northern Rocky Mountain region, in the form of an intense High. It will travel southeastward to the center of the continent, and often to the Gulf if it is preceded by an active Low that is located on a low latitude, as the latter will draw southward the frosty air of the High; after that the course of the storm will be more nearly eastward. Now it is of rare occurrence that a cold wave gains entrance to any considerable area of our territory without warning, but in the early days of the Weather Bureau they too often reach Iowa, or States farther east, without any notice whatever. It was then discovered that a certain type of weather map preceded such failures of the forecaster. One who is interested in gaining early knowledge of the approach of a cold wave to the United States should watch not only for the appearance of abnormally high barometer readings, from the stations of the Canadian Northwest, or from Montana and North Dakota, but especially for a crescent-shaped Low, with one horn of the crescent touching Lake Superior and the other extending into the middle Rocky Mountain region, at about Colorado. This Low will appear to be an innocent affair; there may be a small secondary Low in each end of the crescent, and no High of

any importance in the northwest, for which one ordinarily would look in anticipating a cold wave. But when this crescent-shaped Low appears on the morning weather map, a High of marked intensity invariably will develop with great suddenness over Montana and North Dakota and bring a cold wave to the Middle Mississippi Valley before the next morning, if the time of year be winter.

Do not forget that the Low is as important as the High in causing a cold wave, for the High that brings the cold air must follow in the track of the Low and will be attracted by the latter in proportion to its lowness, as indicated by the isobar inclosing the center of the Low. A cold wave will reach the Gulf only if the preceding Low originate in Texas; it will be confined to the Ohio Valley as the limit of its southern influence if the preceding Low originate in Colorado; and it will only skirt the northern border of the United States and the Lake region if the Low begin in Montana.

More and more is man applying science to commerce and industry. When the weather map, which was unknown but little more than half a century ago, indicates the formation of a heavy body of cold air in the extreme northwest, the chief official forecaster at Washington is on the alert;

he orders special observations every few hours from the Weather Bureau stations directly within and well in advance of the cold area, and as soon as he becomes satisfied that a cold wave is on its way, the previously arranged system of disseminating warnings is brought into action, and by telegraph,

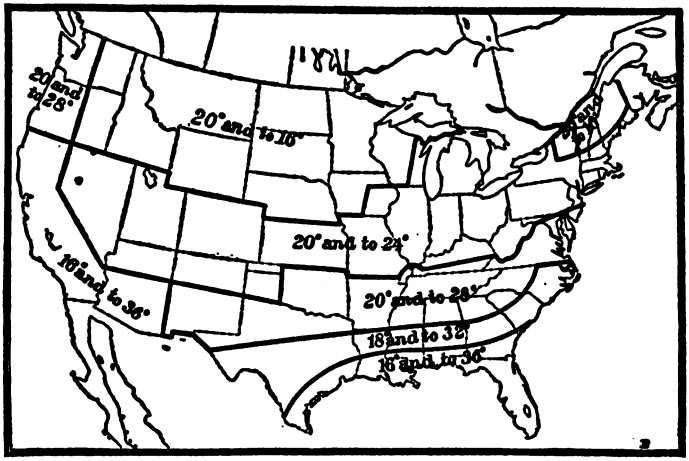


CHART 6. — COLD WAVE ZONES, MARCH TO NOVEMBER. AMOUNT OF FALL AND VERIFYING LIMIT.

telephone, flags, whistles, bulletins, and other agencies, the people in every city, town and hamlet, and many in the stock and farming regions, are notified of the advancing cold twelve to twenty-four hours before it reaches them.

Charts 6 and 7 show how the Weather Bureau defines a cold wave. There must be a fall of sixteen degrees, eighteen degrees, or twenty degrees

within thirty-six hours and a certain degree of coldness must be reached. The charts show that what is a cold wave in the Gulf region is far from one in the northwest.

Chart 8 shows the lowest temperatures experienced in the United States since the founding of the

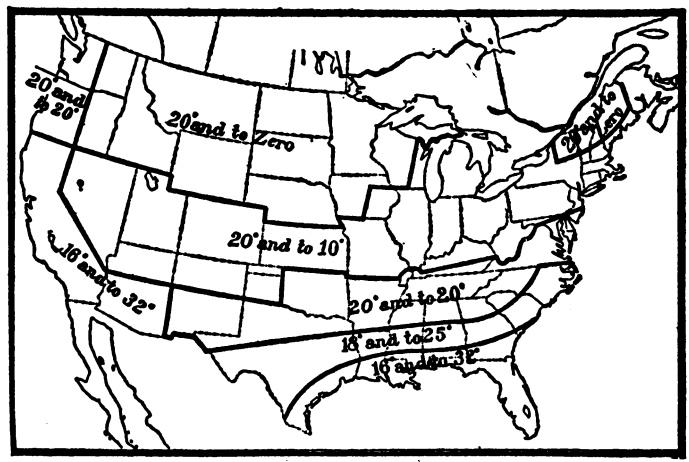


CHART 7. — COLD WAVE ZONES, DECEMBER, JANUARY, AND FEBRUARY. AMOUNT OF FALL AND VERIFYING LIMIT.

Weather Bureau, 1871 to 1913. Note the influence of the Pacific Ocean in forcing the zero line from Arizona northward to British Columbia.

Chart 9 shows the number of times that a cold wave occurred at each station of the Weather Bureau for a period of ten years. The number is greater for northern New England than for the Red River

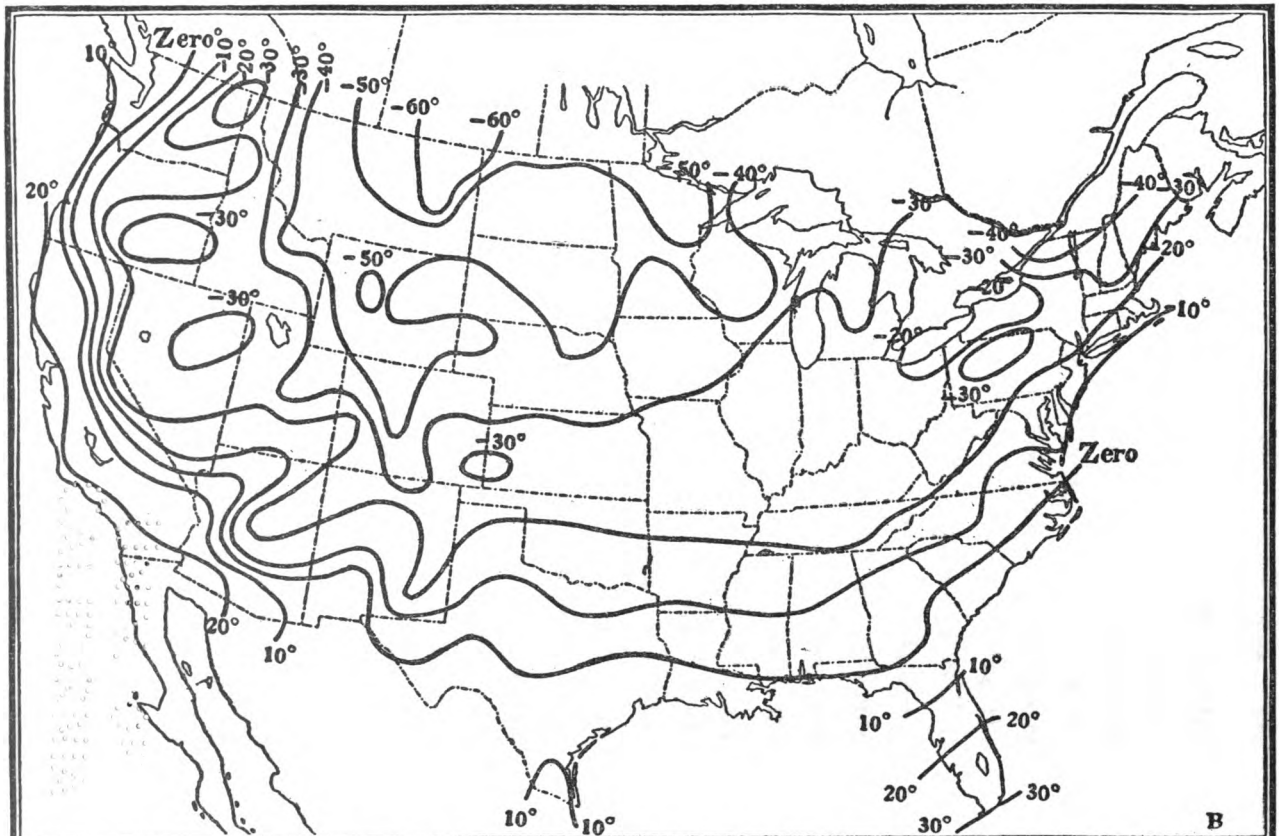


CHART 8. — LOWEST TEMPERATURES IN THE UNITED STATES, 1871–1913.

of the North Valley, because practically all the cold waves that cross Minnesota reach New England; and the latter also receives fierce boreal visitors that come to it from the Hudson Bay region lying directly northeast, which do not visit any portion of Minnesota or the region farther west. During the period not a single technical cold wave occurred at the coast stations of California, Oregon, or Washington, while Red Bluff and Sacramento were the only two places in California west of the Sierras, and Roseburg, Oregon, the only station west of the Cascade Range that had any, the numbers being one, two, and five respectively. In the Florida peninsula south of Jacksonville, Tampa had two, while none occurred at Miami. Sometimes the temperature falls lower than that required for a cold wave, but not within the period of twenty-four hours required by the regulations. A notable case in point is the severe cold wave in California in January, 1913, the lowest temperature ever observed being recorded at San Diego on the 7th, when the minimum fell to 25°.

Cold Waves Tempered by Great Lakes. The severity of cold waves is markedly modified by the Great Lakes, especially in the fall and the first part of winter, before much of the water surface is covered

with ice and snow. Not only is the number of cold waves much less at stations of the Lakes than at near-by places in the interior, but there is a marked variation in the number that occur at the Lake stations, depending upon which side of the lake and how close to the water the station is located. The most striking differences are noted in the Lake Michigan region, the number on the west shore being five or six times as great as on the east side. Milwaukee shows a count of forty-seven as compared with nine at Grand Haven. This lake influence affects the entire Lower Michigan peninsula, but it is not so great in the interior and eastern sections as along the west shore, Grand Haven's nine standing out against fourteen, fifteen, and twenty-three for Grand Rapids, Detroit, and Port Huron. A similar condition is noted in New York State; Buffalo, Rochester, and Oswego, near the lake shore, had twenty, twenty-seven, and twenty-nine cold waves respectively, while the interior stations of Ithaca, Binghamton, and Syracuse had thirty-eight, forty-five, and fifty-two.

Cold Waves Tempered by the Heat of Cities. Another reason for the lack of uniformity in the recorded number of cold waves in the various sections of the country is the difference between city and

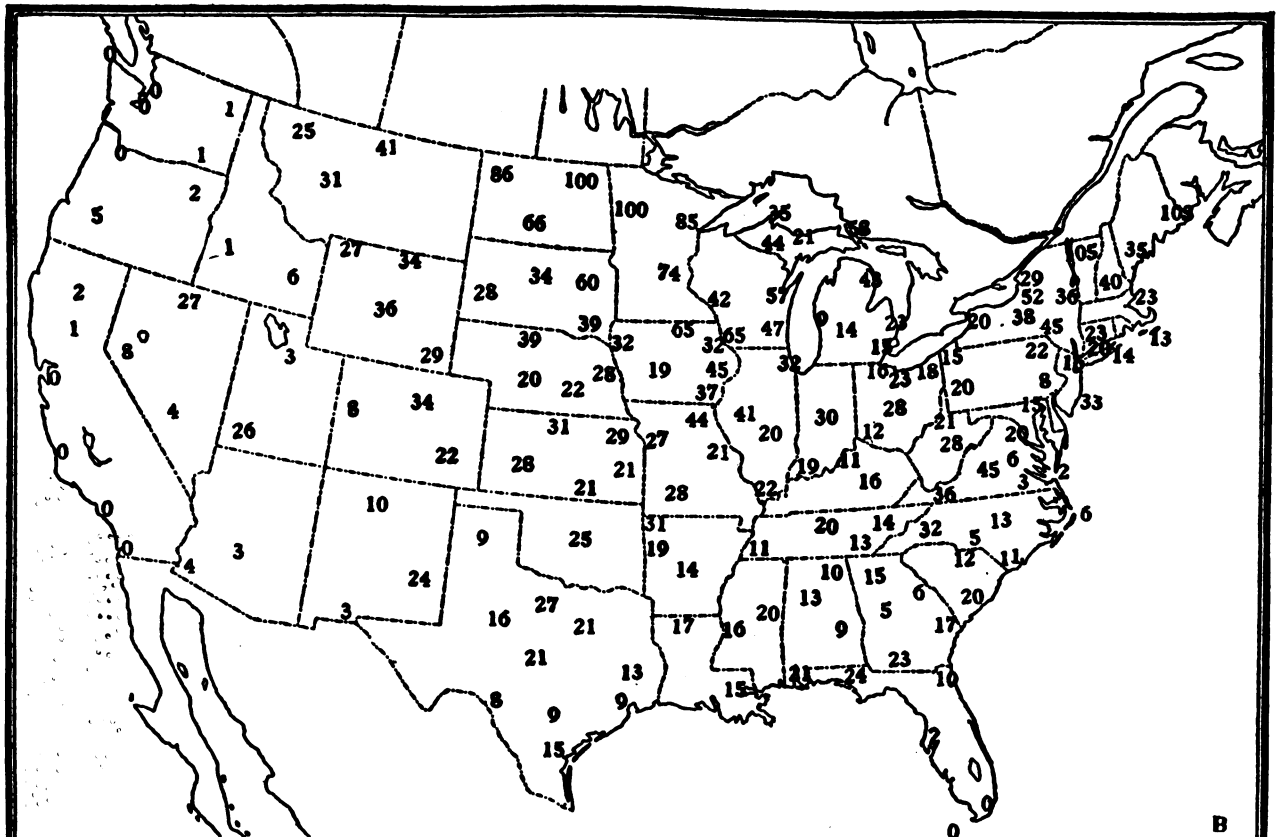


CHART 9. — NUMBER OF COLD WAVES, 1904–1914, INCLUSIVE.

suburban temperatures. Stations located in small villages or in the open land will show a greater number of recorded cold waves than those located in large cities, where the heat stored up by pavements and brick buildings during sunshine each day, and where the heat from thousand of chimneys, and maybe millions of human beings, holds the minimum temperature of night much above that of the free air in the open country. Charles City, where the instruments have open country exposure had sixty-five cold waves, which far exceeds the number recorded at any other station in Iowa.

No matter how severe may be the cold wave that appears in the northwest, it will not extend over Wyoming, Colorado, Utah, and any region south of them, unless the center of the High extends well over the Rocky Mountain Divide. Otherwise it will come down the east slope of the mountains and the cold will not cross them.

In the Lows the conditions of the air and its movements are exactly the reverse of what they are in the Highs; the air is warmer and moister, it is drawn spirally inward from all directions instead of being forced outward as in the High, and it ascends as it approaches the center of depression, sometimes causing rain or snow as it cools by expansion during

its ascent. While the air cools with ascent in the Low at the same rate that it warms with descent in the High, the earth experiences a general warming effect with the passage of the Lows, because the air falls but little in temperature as it rises before it reaches its dew point, and then there is a liberation of the latent heat of condensation (see Chapter V); and what is more important, there is formed a covering of clouds that checks or wholly stops radiation outward from the lower air. However there are times when the passage of Lows produces a cooling effect. This is when abnormally hot weather has prevailed for some days; then the air may be mixed, washed, and cooled by thunder showers.

Highs and Lows alternately drift across the continent in periods of about three days each. They are a part of the divine economy that provides for the seedtime and the harvest, for, as previously stated, the Lows draw the warm, vapor-bearing currents inland from the Gulf and the ocean and cause them to deposit their moisture far to the north and west. Four sevenths of all our storms come from the middle or the north plateau regions of the Rocky Mountains, or at least enter our field of observation from those regions, and pass from this arid or subarid section of the continent easterly over the Lakes

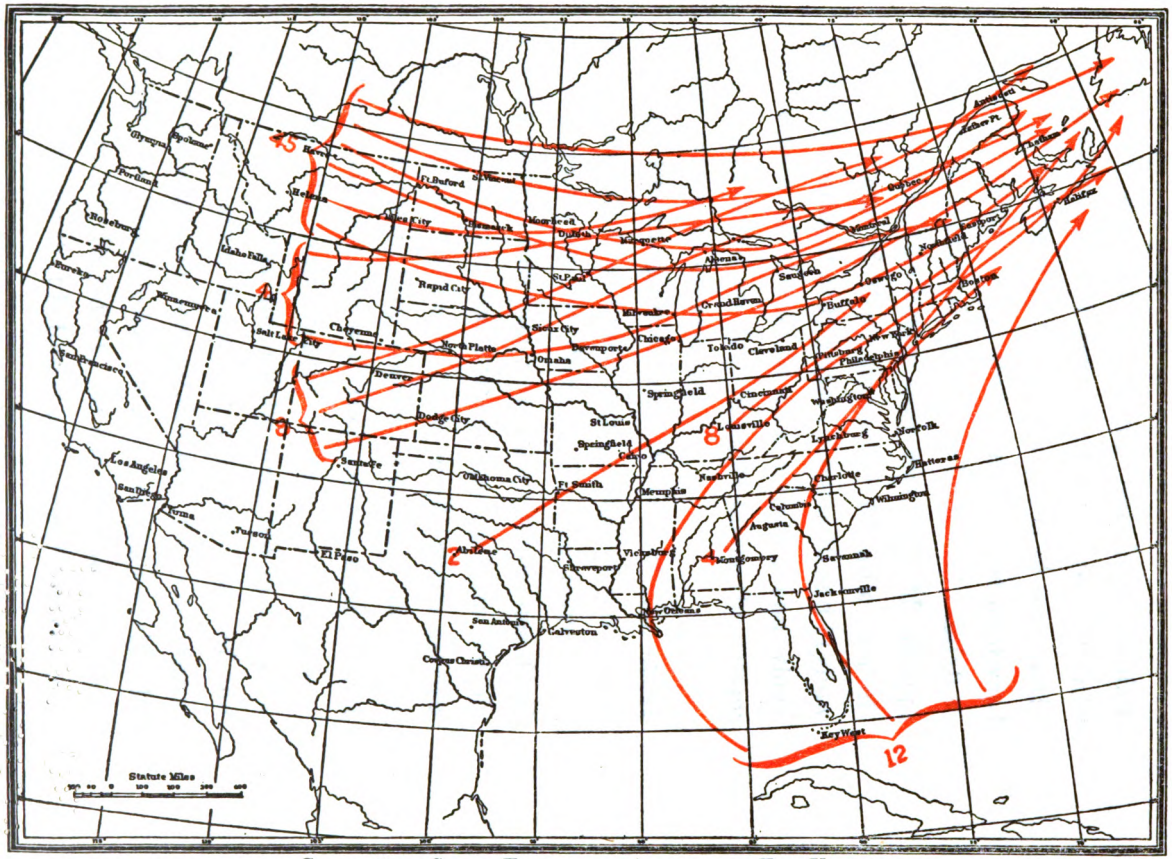


CHART 10. — STORM TRACKS FOR AUGUST FOR TEN YEARS.

and New England, producing but little rainfall. The greater part of the remaining three sevenths are first observed in the arid regions of our southwestern States; they always move northeastward and can be depended on to give bountiful rainfall so soon as or a little before they reach the Mississippi River. Some of them cross the Atlantic and affect the continent of Europe. Charts 10 and 11 show the courses of storms in this country, and where they originate, or are first brought under the survey of our system of observation.

West Indian Hurricanes. A few of the most severe storms that touch any portion of our continent originate in the West Indies and travel in a northwesterly direction until they touch our Gulf or South Atlantic coast, when, passing from the influence of the northeast trade winds which carried them westward, they recurve and pass along our eastern coast, usually with their centers offshore and following the Gulf Stream. These violent atmospheric convulsions are usually detected in the process of formation through the effectiveness of the storm-warning service established by the writer during the Spanish-American War, under the direction of the President, for the purpose of giving warning to our fleet before the coming of a hurricane.

The President realized the great part played by storms in many of the naval battles of the past, and it may be surmised that he was more afraid of a West Indian hurricane than he was of the Spanish Navy. But Cervera was beaten and the blockade was raised before the hurricanes of 1898 began.

Galveston Hurricane. The new Weather Service, with a cordon of stations down the Windward Islands and along the north coast of South America, surrounding our fleet, and inaugurated as a war measure, so demonstrated its value in locating and giving warning of the coming of a hurricane soon after the end of the war that Congress continued it as a permanent instrument of peace; and when the destructive Galveston Hurricane occurred in 1900 it detected the storm at its inception and so fully advised shipping of the storm's movements that not a vessel was lost as the storm roared and gyrated across the Gulf of Mexico and crashed upon the Texas coast, destroying a large part of the city and drowning six thousand people.

The hurricane is simply a rapidly gyrating cyclone; it usually is only one to three hundred miles in diameter. The storm that destroyed Galveston moved across the Caribbean Sea at the rate of only about eight to ten miles an hour. It increased its rate as

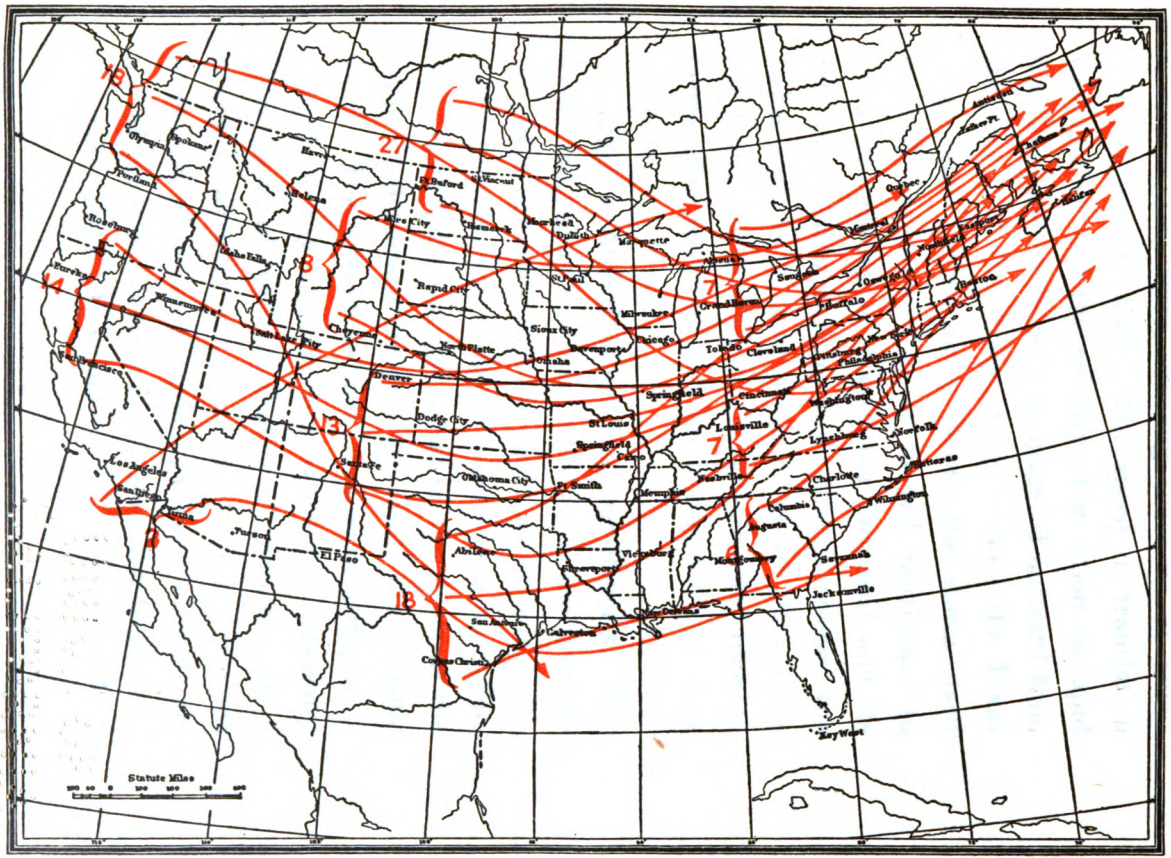
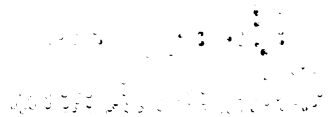


CHART 11. — STORM TRACKS FOR FEBRUARY FOR TEN YEARS.



it moved northward, crossing the Gulf at about fifteen miles per hour. The speed of translation was so slow and the velocity of gyration so rapid that immense swells were propagated outward from the center of the storm; they reached the Texas coast some sixteen hours before the storm itself reached Galveston. As it moved northward to Iowa its velocity of translation increased and its rate of gyration decreased, so that it crossed the Lakes with both movements at about sixty miles per hour. At Galveston the anemometer blew to pieces after recording one hundred and thirty miles per hour.

Danger to Atlantic Coast Summer Resorts. The writer frequently has been asked as to the possibilities of a populous Atlantic coast resort being submerged by the waters driven inshore by a hurricane, or being lifted up in the center of the storm as the result of decreased air pressure inside the cyclonic whirl. The answer is that such a catastrophe is possible to any Atlantic coast city (more especially those south of Norfolk) that is not protected by a heavy breakwater of ten to twenty feet above sea level, and whose building foundations and walls are not of brick or concrete for at least ten feet above the water level. It would be necessary for a West

Indian hurricane of unusual intensity — one similar to that which wrecked Galveston — to be considerably deflected westward out of its normal track in order to hit one of our coast cities north of Chesapeake Bay so that the center of the storm would pass over it, or near enough to cause destruction. In Galveston there was little damage to strongly constructed buildings of brick or stone.

The Breaking of Droughts. It is most important for the forecaster to know when and how droughts may be broken. He will observe that when the great cereal plains are famishing for moisture the Lows all originate on the middle or north Rocky Mountain plateau, in the region of Colorado or Montana, and that the drought continues until the Lows begin to form in the extreme southwest — in Arizona, New Mexico, or Texas. As previously stated such Lows always bring rain as they move northeastward.

Warm Waves. There come in summer periods of almost stagnation in the drift of the Highs and the Lows across the continent. At such times if a High be centered in the South Atlantic Ocean, with its center at Bermuda, and its western limits extending into the South Atlantic coast States, there will result what is popularly known as a warm wave, for the air will slowly and steadily move from the

southeast, where the pressure is greater, towards the northwest, where it is less; it will receive constant accretions of heat from the radiating surface of the earth, and finally attain to a temperature that is extremely uncomfortable to all forms of life, that lowers the physical stamina, and that largely increases the death rate. This superheated condition of the lower stratum of air in which we live continues until a Low develops in the southwest and a High in the northwest, which relation, as we already know, soon brings rainfall to the interior of the country.

V-shaped Lows are reasonably sure to cause precipitation, and if the barometer at the center of the Low be five to seven tenths below the outer limits of the depression, heavy precipitation and destructive local storms may be expected.

Thunderstorms. The thunderstorm is caused by cold and heavy air from above breaking through into a lighter and superheated stratum next the earth. Some of them have a horizontal rolling motion which throws forward the cool air in the direction in which the storm is moving. It seldom is more than five or ten miles in width and twenty to thirty miles in length. In general, thunderstorms move from the west toward some eastern point, more often southwest to northeast.

The frequency of thunderstorms is the greatest with ill-defined Lows whose pressure is but little below the normal air pressure of thirty inches. Any depression of the barometer slightly below the level at surrounding stations — such as occurs when a weak High of only thirty inches, or thirty and one tenth inches, breaks up into two or more areas, with slightly lower pressure between them — is fruitful of thunderstorms. A High of but modest intensity advancing eastward into a region of slightly lower pressure and much higher temperature causes thunderstorms along its eastern front. A temperature of 80° on the morning weather map, with a high humidity, seldom can endure beyond the second day without a break and the coming of cooling thundershowers. Any Low with abnormal heat and humidity in its southeast quadrant is usually attended with numerous thunder squalls in the regions of high temperature and moisture.

Of the thunderstorm days in the United States few occur in the Rocky Mountain regions or in northern New England. The greatest number is in Florida and the Gulf States and thence northward up the Mississippi Valley.

The Moon Has No Influence on the Weather. The moon used to be the farmer's most valued

friend as a forecaster of the weather and as a guide in the planting of crops, but a higher order of intelligence is causing this fallacy to pass away. The moon's nearness to the earth and the fact that its phases occur in about seven days, which is about twice the period of storm recurrence, in the minds of many have endowed it with potency in the influencing of our weather. Rain may occur on the same day of the week for several weeks in succession, but only occasionally, while the moon is constantly progressing from one phase to another. The few cases that prove the mistaken theory are taken as proof conclusive, while the many cases that do not prove acceptable to the moon forecaster are ignored and not mentioned to his friends nor even acknowledged to himself. One is reluctant to have a belief disproved, no matter how ridiculous it may be. In fact, the more untenable it is, the more tenaciously some adhere to it, as though they were loyally standing by an old friend who had made mistakes, but who still was good at heart. The attraction of the moon, because of its nearness and notwithstanding its small mass, is far more potent in the raising of the tides of the ocean than is the sun, but its attraction on our atmosphere produces a tide of only four thousandths of an inch of the barometer, an

influence that is shadowy and without the least influence in causing storms, or changes of any kind in the weather; and there is no possible way in which the moon could influence the germination of seed or the growing of crops.

Equinoctial Storm. As the summer wanes the Lows become more pronounced and the sporadic showers give place to general rain storms along in September. There is no objection to these storms being known as "Equinoctial", except that any date in the latter half of September is as liable to show a beginning of these storms as is the 21st or the 22d. The equinox simply marks the middle period in the transition from one type of weather to another.

Forecasting from Halos. The halos that sometimes surround the sun or the moon indicate the coming of precipitation to the extent of making manifest the presence in the upper air of large quantities of vapor of water in a congealed state. When the vapor of water cools quietly in the laboratory it frequently forms minute spheres of water, which, strange to relate, may remain liquid all the way down to zero and below; but if touched or jostled they instantly turn to ice, in the form of spiculæ, or needles; they are simply hexagonal slender prisms capped by hexagonal pyramids. These

needles rotate or spin about as they fall. The geometrical relations of the facets of the crystals to the axis of rotation and to the line along which they fall are a complex problem in optics. Suffice to say that the observer, looking through a filmy cloud of such crystals, would see in one part of the sky a halo, in another part an arc of light, and in other directions bright spots like the sun, all of them arranged symmetrically with regard to the sun and the observer's zenith. A lunar halo is a large ring concentric about the moon. A secondary halo surrounds the first. Mock suns or mock moons may appear coincident with solar or lunar halos. The ice prisms through which one sees the phenomena both refract and diffract the light as it passes through the cloud and by partly decomposing the rays render visible a part of their elementary colors. The red is on the inside, next to which is a little yellow or green, with bluish white on the outside. In coronas, which are much smaller, the red is on the outside. A detailed description of these phenomena may be found in Moore's "Descriptive Meteorology" (Appleton).

Tornadoes. The cyclone has a diameter of a thousand to two thousand miles, the hurricane about one to three hundred and the tornado only one to

ten hundred *feet*. The hurricane is much more destructive than the cyclone, and the tornado is incomparably greater in velocity of gyration and rending force than the hurricane. New England, Florida, and the wide region including the eastern slope of the Rocky Mountains westward to the Pacific are nearly free from the atmospheric convulsions that cause the tornadoes, and they are infrequent in any Atlantic coast State, but numerous in the States bordering on the Mississippi River, and in the eastern halves of Oklahoma, Kansas, and Nebraska. During a year of great frequency of tornadoes, about ninety storms occurred, while during some other years the number has been as low as twenty. The direction generally is toward the northeast. The average rate of movement of the tornado cloud is about twenty-five miles per hour and the width of its destructive path only five hundred to one thousand feet; the time of passage is less than half a minute. It does not come upon one unseen and unheralded. Many times the advancing funnel-shaped clouds may be seen, and they always are accompanied by a great roar which may be heard for miles. Except a tornado cellar, the cellar of a frame house is the safest place. The writer has examined either the wrecks or the records

of hundreds of tornadoes and does not know of a single case of a person being killed by a tornado in the cellar of a frame house. If one is in the open and a tornado approaches, never flee to the north or to the east, but rather to the northwest, and one needs to travel but a short distance to pass out of the track of the monster. The tornado always twists counter clockwise, the same as the cyclone in whose southeast quadrant it nearly always occurs. On the southeast side of the path there are indrafts; so that it is safer, unless the track of the oncoming storm is clearly seen to be well to the north of the observer, for one to run toward the northwest. Persons have stood near to the north side of a tornado track during its passage without suffering injury. If a cave, the cellar of a frame house, or a narrow ditch cannot be reached, the best thing to do is to lie flat on the ground as far from buildings and trees as possible.

The tornado is essentially an American storm, doubtless caused by the running together, in the southeast quadrant of a cyclone, of cold northwest currents and warm winds from the southeast, at a time when the latter are saturated with moisture. They are confined almost entirely to the region between the two great mountain systems of the

continent, none occurring in the Rocky Mountains and but few east of the Alleghanies. The north-and-south trend of our mountain systems, quite different from the systems of Europe and Asia, facilitates the coming together of conflicting winds of widely different temperatures in the lower reaches of the atmosphere where there is an abundance of water vapor; no tornadic whirls probably can occur without an abundance of water vapor and the energizing effect of the heat liberated in the whirling cloud as this vapor is suddenly carried aloft and liberated by condensation right in the center of the disturbance. Because of the relation of the trend of its great mountain systems to its oceans, the United States occupies a somewhat unique position meteorologically in the world. Its atmospheric conditions are more active than those of any other continent, which conditions are beneficial to the people of this country.

When to Watch the Weather Map for Tornadoes. The four conditions essential to the formation of tornadoes are as follows:

1. A cyclone, the center of which is to the north or northwest;

2. An isotherm of 70° or over extending from the southeast well up into the center of the cy-

FIG. 17. — TORNADO CLOUD.

clone, and then passing outward toward the southwest, all inside the southeast quadrant of the Low;

3. Excessive humidity;
4. Time of year March 15 to June 15.

If any one of the four foregoing conditions be absent, tornadoes are not liable to occur. The reason why spring and early summer is the time when tornadoes are most frequent is because the earth and a thin stratum of air immediately next the earth are heated up rapidly with the gaining heat of the sun's rays in the spring, while the air a short distance aloft still retains much of the cold of winter. At this time cyclonic action may bring together air masses of widely different temperatures, especially when the upper layers on the west side of the Low are drawn down and commingled with the hot and humid surface winds of the southeast quadrant.

Tornadoes Not Increasing. The writer does not indorse the theory that the number of these storms is increasing; that the breaking of the virgin soil of the prairie, the planting or the cutting away of the forests, the drainage of land surfaces by tiles, the stringing of thousands of miles of wire, or the laying of iron and steel rails have materially altered the climate or contributed to the frequency or the intensity of storms. To be sure, as population

becomes more dense greater destruction will ensue with the same number of storms.

Difficult to Forecast Tornadoes. It is not possible for the forecaster to warn the exact cities and towns that will be struck by tornadoes without unduly alarming many places that will wholly escape injury. What we know is that tornadoes are almost wholly confined to the southeast quadrant of a cyclone, and that when the thermal, hygrometric, and time conditions are favorable, a region about one or two hundred miles square will be sacrificed by a number of these atmospheric twisters. One of the most destructive tornadoes of record devastated St. Louis in the afternoon of May 27, 1896. The abnormal heat and humidity of a rather small and weak cyclone centered in eastern Kansas on the morning weather map of that day, caused the Weather Bureau to distribute tornado forecasts at 10 A.M. throughout all of Missouri. The schools of St. Louis were dismissed and the children sent home on receipt of the warning, and although some eight or ten separate tornadoes touched various parts of the State and the people were prepared for their coming, so many people were terrorized by the warning in communities that were not harmed, that the writer, then Chief of the Weather Bureau, at

FIG. 18. — THE ST. LOUIS TORNADO OF MAY 27, 1896, SHOT A PINE SCANTLING THROUGH THE IRON SIDE OF THE EADS BRIDGE.

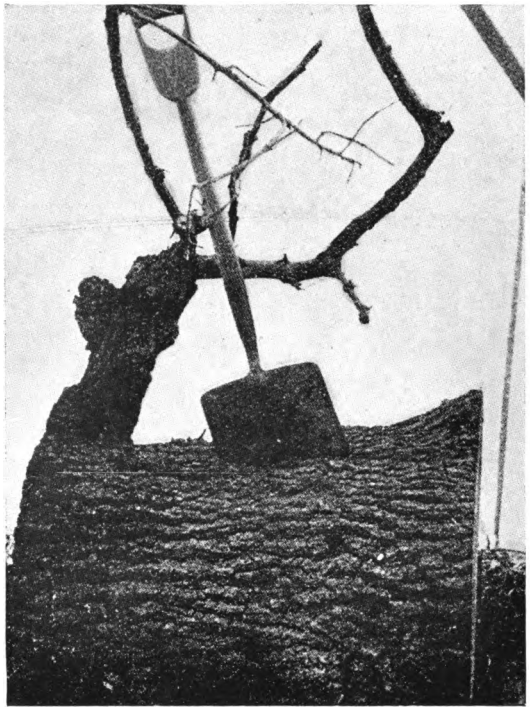


FIG. 19. — THE ST. LOUIS TORNADO OF MAY 27, 1896, SHOT A SHOVEL SIX INCHES INTO THE BODY OF A TREE.

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once issued orders forbidding the specific forecasting of tornadoes in the future. Under tornadic conditions the forecast is for "conditions favorable for severe local storms."

Freaks of the Tornado. The writer was in St. Louis the day after the storm and spent much time in examining the wreckage. He was impressed with the fact that some buildings were burst outward and that all four walls fell away from their bases, indicating that the tornado cloud must have lifted and dropped down over them in such a way that the partial vacuum that is created by the rotating cloud through centrifugal force so reduced the pressure of the air on the outside of the houses that the normal pressure of fifteen pounds per square inch exploded them. He saw bricks in a plastered wall that were neatly cleaned of all plaster by the expansion of the air inside the brick, as the air pressure from the outside was reduced. He saw a two by four pine scantling shot through five eighths of solid iron on the Eads Bridge, the pine stick protruding several feet through the iron side of the roadway, exemplifying the old principle of shooting a candle through a board. He saw a six by eight piece of timber driven four feet almost straight down into the hard compact soil, a gardener's spade

shot six inches into the tough body of a tree, a chip driven through the limb of a tree, and wheat straws forced into the body of a tree to the depth of over half an inch. Such was the fearful velocity of the wind as it gyrated about the small center of the tornado, — a velocity exceeding that of any rifle bullet. (See Figures 17, 18, 19, and 20.)

Some have advocated the planting of trees to the southwest of cities in the regions where tornadoes are frequent, so that the tornadoes may expend their energy in uprooting the trees before they come to the city, but this storm traveled through several miles of brick buildings, razing them to the ground and almost pulverizing them and still left the city apparently with greater force than it had on entering. The largest trees would offer no more resistance to a tornado cloud than would so many blades of grass.

When the official forecasts contain the statement that conditions are favorable for "severe local storms" it would be well to carefully observe the formation of portentous clouds in the west and southwest, between 3 and 6 o'clock in the afternoon, and if one with black, ragged fringes on its lower edge and accompanied with a noise like several railroad trains makes its appearance, seek safety in the cellar of a frame house.

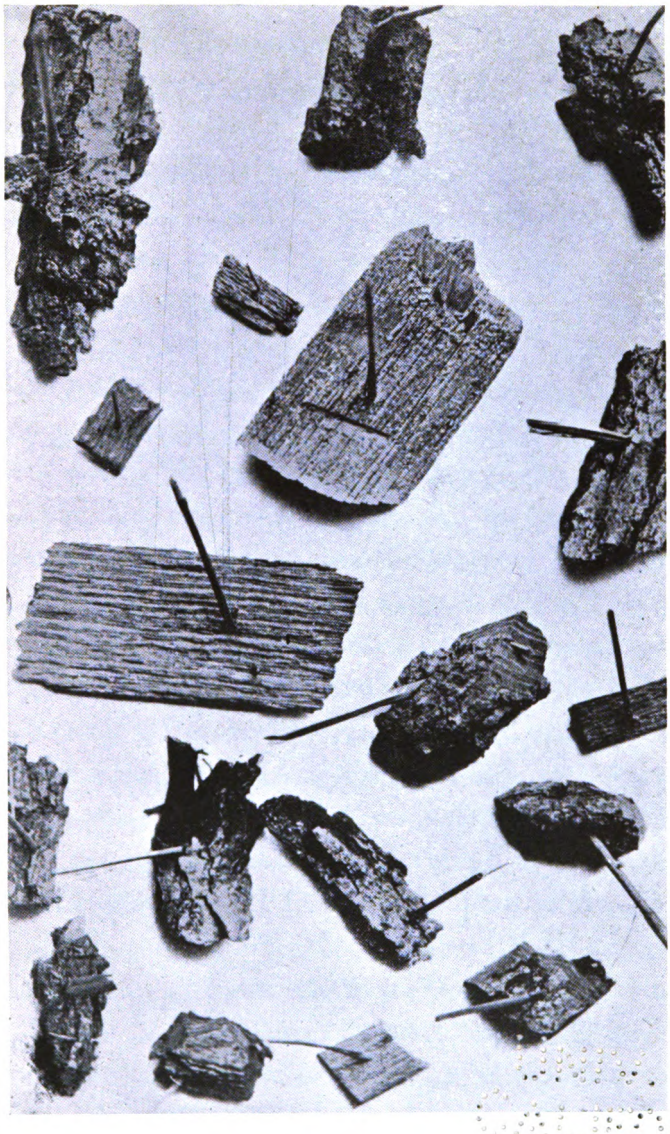
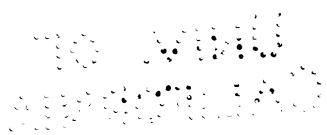


FIG. 20. — THE ST. LOUIS TORNADO DROVE STRAWS ONE HALF INCH INTO WOOD.



General Rules for Forecastings. What has gone before in this chapter gives an idea of what guides the weather forecaster in making his deductions. In brief, he studies the developments and the movements of the Highs and the Lows during the past two or three days, as shown by preceding weather maps, and from the knowledge gained forecasts the future course and intensity of the fair and the foul weather areas for one, two, or three days in advance. By preserving the weather map each day and noting the movements of the Highs and the Lows, any intelligent person can make a fairly accurate forecast for himself, always remembering that the Lows, as they drift towards him, will bring warmer weather and sometimes rain or snow, and that as they pass his place of observation the Highs following in the tracks of the Lows will bring cooler and fair weather, except during periods of extreme summer heat, when the Lows bring showers that cool the parched earth; and except in the north Rocky Mountain plateau, where most of the precipitation occurs after the center of the Low has passed and northwest winds are blowing.

The amateur weather forecaster can closely anticipate the temperature of his region by remembering that the weather will be cool and the humidity

low so long as the center of the predominating High (the High inclosing the greatest area within the thirty-inch isobar) is north of his latitude, either northeast or northwest, and that it will be warm so long as the High is south of the parallel of latitude that passes through his section of country.

He will find that the centers of the Lows will follow closely the direction indicated by the isotherms that lead eastward out of their centers, and that they move across the country from the west in quite regular succession, and that the frequent changes from sunshine to clouds and from warm to cold are the result of the mixing of the air by these atmospheric eddies.

Experience will teach him that Lows from the southwest are reasonably sure of causing precipitation, and that if his temperature be sufficiently low — anywhere from zero to 20° — the fall will be in the shape of snow; that Lows that only skirt our northern border will be deficient in precipitation, even if they cause any at all; that the slow settling of a High over the South Atlantic States means heat for all the rest of the country east of the Rocky Mountains in degree that will be dependent upon the magnitude and the intensity of the southern High; that the heat will continue, even if tem-

porarily interrupted by showers, so long as this High retains its location in the southeast; that tornadoes occur in the spring of the year when Lows have excessive heat and humidity in their southeast quadrants; that V-shaped Lows cause violent local storms, if not tornadoes, and often deluges of rain; and that frosts may be expected in the country when a minimum temperature of 40° is forecast for the city; and that the severity of cold waves modifies as they come eastward, and that they will only flow as far south as the area covered by the Low that preceded them, — that is to say, by that part of the Low included in the thirty-inch isobar, or by a close approximation to such area.

National Forecaster E. H. Bowie, known to the writer as one of the ablest forecasters ever developed by the Weather Bureau, in a recent most valuable publication by the Bureau, entitled "Weather Forecasting in the United States", formulates rules for forecasting as follows:

1. When there is an area of high pressure over the southeast and a cold wave in the northwest threatens, there will be a storm development in the southwest and precipitation will be general.

2. If a storm form in the southwest and be forced

to the left of a normal track (Charts 10 and 11), another storm will immediately begin to develop in the southwest and it becomes a sure rain producer. Storms that develop in the southwest and move normally are quickly followed by clearing weather.

3. Troughs of low pressure moving from the west are of two types — the narrow and the wide. The former moves eastward slowly and storm centers develop in the extreme northern and the extreme southern ends. When the trough is wide, the development of an extensive storm area is not uncommon, especially if the wide intervening area between the Highs shows relatively high temperatures.

4. When the northern end of a trough moves eastward faster than the southern end, the weather conditions in the south and southwest remain unsettled and the chances are that a storm will form southwest of the High that follows. When the southern end moves faster than the northern end, settled weather follows.

5. Storms that start in the northwest and move southeastward do not gather great intensity until they begin to recurve to the northward. At the time of recurving they move slowly, as a rule, and care must be exercised in predicting clearing weather.

6. Marked changes in temperature in the southeast and northwest quadrants imply an increase in the storm's intensity. Small temperature changes do not indicate a further development of the storm.

7. Abnormally high temperatures northwest of a storm indicate that it will either retrograde or remain stationary.

8. East of the Rocky Mountains, a storm which moves to the left of its normal track increases in intensity.

9. Storms with isobars closely crowded on the west and northwest generally move slowly and to the east or southeast, and the precipitation and high winds are maintained unusually long in the northern and western quadrants.

10. Storms with the isobars closely crowded in the south and southeast quadrants move rapidly northeastward and the weather quickly clears after the passage of the storm center.

Rules for Making Local Forecasts. As an illustration of what may be done by the local observer or the layman in formulating rules of weather forecasting for his immediate vicinities, the following rules, which were evolved by the writer in 1892, while serving as the Weather Bureau local forecaster for Milwaukee, Wisconsin, are subjoined:

1. In summer warmer weather occurs after the center of the Low has passed a little to the east, and southwest winds are blowing, because the easterly winds, which otherwise would be the warmest winds, are cooled by passing over the lake.

2. A Low from the northwest that reaches western Minnesota and western Iowa without precipitation or clouds will pass over Wisconsin as a dry Low, unless the isobars are closer than five eighths of an inch.

3. Light frosts will occur on clear, quiet nights in the cranberry marshes when minimum temperatures at Duluth and La Crosse fall to 40° and 45° respectively. When these stations record five degrees lower the frost will be killing in the cranberry marshes and light in the tobacco fields of the southern counties of the State.

4. No frost will occur in the counties bordering on Lake Michigan until the temperatures at the Weather Bureau stations fall close to the freezing point, such is the influence of the lake in storing up heat and slowly radiating it during the night; and on the eastern side of the lake its protecting influence is much greater.

5. When the wind sets in from points between south and southeast and the barometer falls steadily,

a storm is approaching from the west or northwest, and its center will pass near or north of the observer within twelve to twenty-four hours, with wind shifting to northwest by way of south and southwest. When the wind sets in from points between east and northeast and the barometer falls steadily, a storm is approaching from the south or southwest, and its center will pass near or to the south of the observer within twelve to twenty-four hours, with wind shifting to northwest by way of north. The rapidity of the storm's approach and its intensity will be indicated by the rate and the amount of the fall in the barometer.

Vast Extent of the Area Brought Under Observation. It is a wonderful panoramic picture of atmospheric conditions which, by the aid of the electromagnetic telegraph and two hundred simultaneously reporting stations, is presented to the eye of the forecaster. Each day the kaleidoscope changes and a new graphic picture comes into view. Nowhere else in the world can the student of the weather find such opportunities.

Early meteorologists studied only the storm of low levels and humid airs, where convection only needed to carry the moist air currents to but a slightly higher elevation before cooling by expansion

would produce condensation and an immediate acceleration of the cyclone by the liberation of latent heat within the region of the upward-moving air in its central area. They never had seen the cyclones of the arid northern Rocky Mountain plateau move down to our Great Lakes with rapidly increasing energy, notwithstanding the fact that there had been little condensation, and hence no addition of the latent heat that Espy supposed was essential to a continuation of storms.

The widely differing elevation, topography, temperature, and moisture of the broad region under observation by the United States Weather Bureau present conditions unequaled for the study of every phase of storm development and translation, or at least such as may be comprehended from data taken on the bottom of the atmospheric ocean; and it is but a matter of a short time when the data for extremely high levels will be added.

Here we see summer cyclones formed under the intense solar radiation that beats down through a nearly diathermanous atmosphere upon the wastes of the Rocky Mountain plateaus; cyclones that, if they form in the northern part of the plateau region, move eastward to our Lakes and thence eastward to the St. Lawrence with scant rainfall;

cyclones that, if they have their origin farther south in the region of Colorado, move into the Ohio Valley and thence to New England with considerably more precipitation; and cyclones that, if they have their origin anywhere in our southwest States or Texas, or enter our region of observation from the South Pacific Ocean, can always be expected to cause general rainfall when they reach the Lower Mississippi Valley and later as they pass up through the central portions of the continent.

Here also one may view the great winter cyclones that originate in the Pacific between Hawaii and the Aleutian Islands and come under our vision as they successfully surmount the formidable barriers of the Rocky Mountains with but little diminution of energy, sweep across our continent with increasing force and heavy precipitation, and within three days pass beyond our meteorological horizon at the Atlantic seaboard only to be heard from several days later as boreal ravagers of Northern Europe.

The great anti-cyclones that constitute the American cold waves drift into our territory from Canadian Northwest provinces, and are studied under rapidly changing conditions during three thousand miles of their course.

West Indian hurricanes, at sea level and in humid

air, which are the most violent of all storms except the American tornado, intrude themselves into the domain covered by the weather map at Florida or the East Gulf coast and usually pass off to the northeast with high winds skirting our southern coast stations.

Permanent Highs and Lows in the Pacific Are Great Centers of Action. Near the end of Chapter XII reference is made to the fact that there is a barrier in the Pacific Ocean that interferes with the movement of storms from the Orient, but which does not entirely stop their progress. Extensive Highs and Lows, sometimes called "Centers of Action" because they do not migrate like the traveling Highs and Lows that cause the alternations of weather that we experience from day to day, are also called Sub-permanent Highs and Lows. They are the parent systems out of which come many of the Highs and Lows that cross the North American continent, and they act as a bar to the free passage of storms from the Far East. As these Sub-permanent areas shift their centers a little to the north or to the south they change the character and the line of movement of the storms and cool waves that come to us, and they alter the general character of the weather for thousands of miles to the east of

them. In the region of Iceland is the center of an extensive Sub-permanent Low that has much to do in controlling the weather of Europe, and there is a Sub-permanent High central at or near Bermuda in the southern part of the North Atlantic Ocean. Whenever the latter is built up by having a migrating High from the North American continent join with it, the whole United States experiences what is called a "hot wave", and the heat continues as long as this Sub-permanent High remains unusually high and extends its western limits to include our South Atlantic States.

The matter in the foregoing paragraph is so important that it will be restated in slightly different form: Whenever either the High or the Low Center of Action (Sub-permanent High and Low), out of which comes nearly all of the migrating Highs and Lows, shifts its normal seasonal position, then storms are erratic and unusual weather occurs over the North American continent and farther eastward. The reason why much the greater number of the storms that cross the United States, the Atlantic Ocean, and Europe originate either in our Rockies, the Canadian Northwest, or just off the Alaskan coast is due to the fact (Chart 1, page 99) that the Low center of action is normally over the middle

and northern Rocky Mountain plateau in summer, and over the Aleutian Islands (Chart 2, page 100) in winter. The High that follows the migrating Low in winter either separates from the center of action central over the Canadian Rockies (Chart 2), or from the one central at Honolulu; if from the latter, the weather will be simply cooler after the passage of the Low, but if the High separates from the center of action in the Canadian Rockies it will constitute a cold wave as it follows a Low southeastward into the interior of the United States and then eastward to the coast.

CHAPTER X

CLIMATE

CHANGE OF SOLAR RAYS INTO LIGHT, HEAT, AND OTHER FORMS OF ENERGY AS THEY ARE ABSORBED BY OUR ATMOSPHERE OR AS THEY ENCOUNTER THE EARTH — TEMPERATURES OF WATER, EARTH, AND AIR — HOW SANITARY HOMES MAY BE CHEAPLY CONSTRUCTED BELOW GROUND, COOL IN SUMMER AND WARM IN WINTER

Difference between Climate and Weather. One may speak of the weather of to-day or of some time that is past, but not of the climate of to-day, or of any day, month, or year that is gone: for the climate of a place is determined by a study of its weather records for a long period of years. Climate changes so slowly that we speak of the movement as a mutation rather than as a change. The time that has elapsed since the discovery of the barometer and the thermometer — about two and a half centuries — is so short as to show little if any change in climate, while the weather changes from day to day.

The Sun Our Only Source of Appreciable Heat. Each one of the stars visible to the eye and many of the millions that are not visible, are suns accompanied by planets. Their conditions are similar to those of our sun, except that most of them are larger than our sun, some a million times larger. But their distance is so great that they exercise little or no influence in the heating of the earth. Light travels at about the rate of 186,400 miles per second, and yet these stars are so distant that if the nearest one had been created at the time of the signing of the Declaration of Independence we still would be in ignorance of its existence, for its first rays of light would not reach us for many years yet to come; and light from some of the remote suns that we call stars requires thousands of years to come. It is apparent therefore that we depend exclusively upon our own luminary for the heat that warms our atmosphere and gives life to the surface of the earth.

Different Temperatures with the Same Quantity of Solar Heat. On the same day of each year at the same place practically the same amount of heat falls upon and into the earth's atmosphere from the sun, but rarely does the same temperature and weather occur, and often there is wide variation in

the weather of the same day of two different years. The first of July may be cold enough to wear an overcoat at midday, or the first of January may be so temperate as to permit the donning of summer habiliments, while, according to the amount of heat received from the sun, there would have occurred the usual seasonal conditions on the days named had there been no other influence than the direct action of the sun's heat. The cause of these seeming inconsistencies is due to the motions of the atmosphere in a stratum only five to seven miles in depth, air cooling by expansion as it ascends in cyclonic whirls and heating as it descends in anticyclonic movements. Condensation, in the form of cloud or rain or snow, also introduces complications, usually producing a cooling effect in summer and a warming in winter. In other words: interference in the uniform and gradual change in temperature, of the lower stratum of air in which we live, from the heat

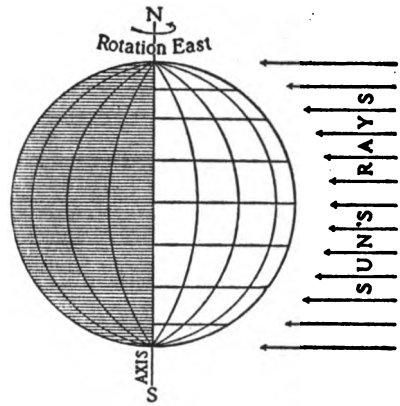


FIG. 21. — Equinoxes, March 21 and September 22. Axis perpendicular to Sun's rays. Day and night everywhere equal.

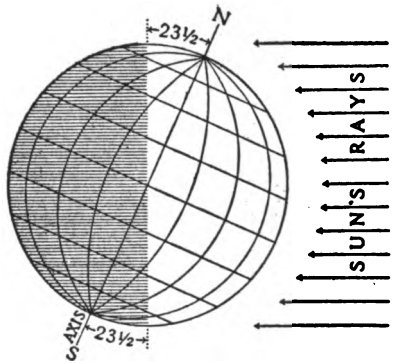


FIG. 22. — Summer Solstice, June 21. North Pole leans towards Sun's rays.

of summer to the cold of winter, and then the reverse process, is due entirely to the heating and the cooling of the lower air by its upward and downward motions.

If the earth's axis were vertical to the plane of its orbit all places on its surface always would have days of twelve hours each and the nights would be of the same length; sunshine would just touch both poles (Figure 21) throughout the entire course of the earth around the sun and there would be no seasons. One would need to change one's location on the earth in order to get a change of weather, which would

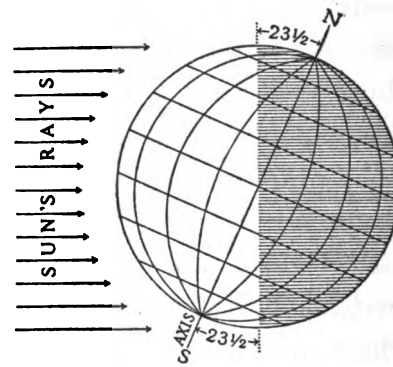


FIG. 23. — Winter Solstice, December 21. North Pole is dark now instead of light, as at Summer Solstice. Pole leans in same direction but Earth being on opposite side of its orbit rays come from opposite direction. Refer to Figure 24.

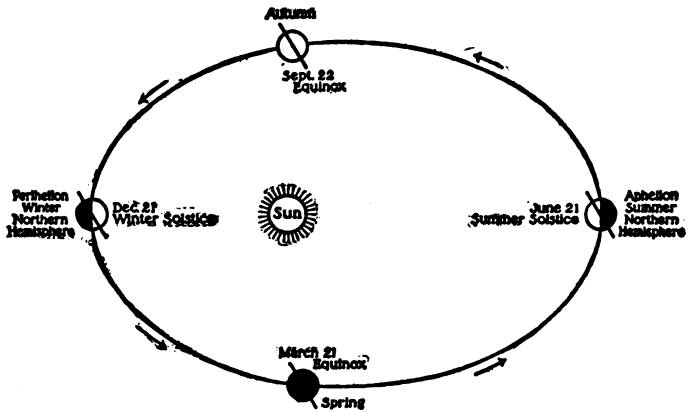


FIG. 24. — Note that direction of axis does not change as Earth moves around Sun. This causes variation in area of surface illuminated. If axis were perpendicular to plane of orbit there would be no seasons.

be monotonous and quite different from the active conditions of the atmosphere that we now enjoy. The whole conditions of life would be altered for

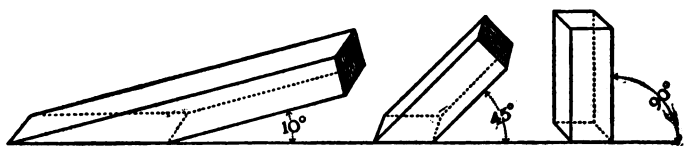


FIG. 25. — As angle of incidence decreases from 90° to 10° the heat received on upper end of blocks is spread over greater area at bottom, and its temperature diminished. (Abbe.)

the worse. You have seen a top tilt over to one side as it spun on the floor. In the same way the earth spins on its axis as it pursues its course around the sun without changing the direction towards which its axis points, as shown by Figure 24.

The intensity of the sun's rays at sunrise and at sunset is less than at midday because the quantity of heat received at the outer limits of the atmosphere on a given area, as for instance at the area of the upper ends of the blocks in Figure 25, passes through a deeper stratum of air the lower the angle of incidence, and because it is distributed over a larger area when it reaches the surface of the earth.

As the heat of day increases from morning until midday and then decreases, so does the heat of the year increase from midwinter to midsummer and then decrease, and for the same reason: change in obliquity of the sun's rays, to which must be added change in distance from the central luminary. Figure 26 shows that the sun reaches its greatest midday altitude on June 21st and its least on December 21st.

Solar Rays Absorbed by the Atmosphere. The atmosphere of the earth absorbs about seventy-six per cent. of the solar rays that pass through it. About one half is absorbed by a cloudless atmosphere, and nearly all is absorbed or reflected away by a cloudy air. On the average about fifty-two per cent. of the earth's surface is obscured by clouds all the time, which reduces the total amount of heat that reaches the earth to but twenty-four per cent.

But in regions like the high plateau of the Rocky Mountains, where there is little cloudiness or moisture in the air, fully fifty per cent. reach the earth. At the equator, when the sun is in the zenith at noon, the rays strike the earth perpendicularly and

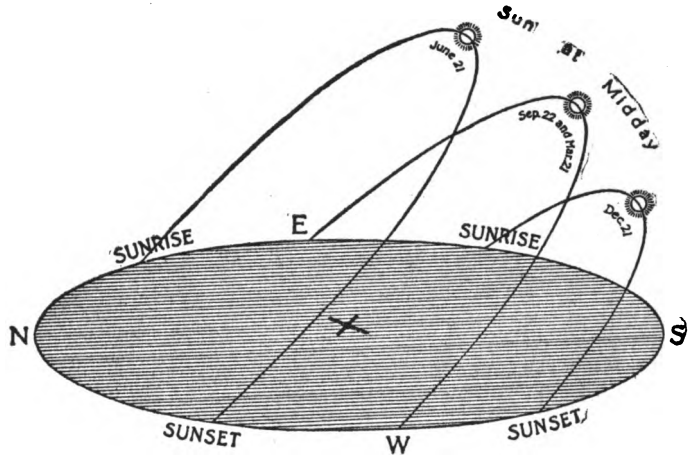


FIG. 26. — Observer at center of picture at latitude 45°. Showing altitude attained by the Sun at midday and length of its track above the horizon at the Summer and Winter Solstices and at the two Equinoxes.

reach the earth through the shortest air distance possible; but for latitudes far north or south of the equator, the rays are more oblique and must pass through an ever-increasing thickness of air as the latitude increases. Consequently the heat that reaches the earth at high latitudes decreases, not only on account of the greater obliquity of the sun's rays, but also because of the longer path of

atmosphere traversed, which causes a further loss by absorption.

The Lag of Earth Temperatures. The solar rays reach their greatest intensity on June 21st, in the Northern Hemisphere, when the sun attains the farthest point north, and the obliquity of its rays is the least, but the highest temperature of the air for the year does not occur on the average for a month or six weeks later, due to the capacity of the earth and air to absorb heat; and the maximum for the earth does not occur until still later. The sun is the farthest south on December 21st, but the minimum air temperature of the year, on the average, does not occur until a month later, and at a later period in the earth. At Munich, Bavaria, at a depth of four feet, the minimum annual temperature occurs on the 2d of March, and the maximum on the 24th of August. For each increase of four feet in depth the time of occurrence of either maximum or minimum temperature is retarded twenty-one days, the minimum not occurring until the 23d of May at a depth of 20.2,° and the maximum being retarded until the 17th of November.

Annual Range in Air Temperature. The difference in temperature between winter and summer increases from the equator northward and from all

oceans toward the interior of continents, and is greater in the middle latitudes on the eastern side of large bodies of land than on their western side. Yakutsk, Siberia, has experienced 80° below zero in January and 102° above in July, making a range of 182°. Dawson, Canada, has a record of 68° below for winter and 94° above for summer, making a range of 162°. In marked contrast with these large differences, shown in the northern interior of continents, is the annual range at Samoa, from a maximum of 92° to a minimum of 62°, a range for the year of only 30° for this island of the Pacific, located near the equator.

Reversal of the Seasons in the Two Hemispheres. The summer is shorter in the Southern Hemisphere than in the Northern and the winter is longer, but the Southern Hemisphere is nearer to the sun in the summer and farther away in winter, conditions that tend to add to the extremes of both seasons. Because of the slowness of the earth in passing through one half of its orbit, the northern summer lasts ninety-three days, while that of the Southern Hemisphere lasts but eighty-nine days. The result is that during like seasons and during the whole year the two hemispheres receive exactly the same quantity of heat.

Only Water Vapor Protects the Earth from Death by Freezing. In Chapter IV you are told that the earth is surrounded by four atmospheres that conduct themselves each quite independently of the others, and that water vapor (aqueous vapor) is one of them. Water vapor plays the most important part in absorbing incoming rays and in absorbing and reflecting back outgoing heat rays from the earth. Without the vaporous atmosphere the sun's rays would be but slightly absorbed as they entered and radiation from the earth would readily escape through the atmosphere to outer space. No matter how fiercely the sun might shine, life on the earth would be entirely destroyed by cold.

When water vapor, clouds, or dust motes intercept certain portions of the sun's rays, they change them from vibrations in ether to the motions of molecules, and the motions of these molecules are expressed in a rise in temperature in the vapor, cloud, or dust. Earth radiations of heat, having longer and slower wave lengths than those that come from the sun, are more readily absorbed by the atmosphere.

One of the principal functions of the atmosphere is to protect the earth from the intense cold of outer space, which must be near or at absolute zero — 459° below the zero mark.

Why Should Not Mountain Peaks Be Warm? They Are Nearer the Sun. The absorption by the atmosphere of both solar and terrestrial radiation is greater in the lower levels of the air, where water vapor, cloud, and dust are the densest, while the transmission of both incoming and outgoing radiation is more rapid through the pure air aloft. Thus we account for the coolness of all mountain peaks, and the perpetual freezing temperatures of some, even though they be located in the tropics, and though their tops occupy positions several miles nearer the sun than the bases from which they rise.

How the Earth Cools at Night. Radiation from the earth goes on day and night, winter and summer. During daylight the gain of heat is greater than the loss, while at night the reverse is true. After sunset both the earth and the air continue to cool by radiation unchecked by the incoming heat of the daytime. The earth loses heat, even under a clear sky, more freely than the air, with the result that the surface of the ground and of vegetation may fall to a temperature ten to fifteen degrees lower than that of the air at a few hundred feet elevation. This condition is called "temperature inversion." The greater difference will occur when there is little wind to mix the air. On a clear night

the radiation outward will be rapid; then, if the wind be light, there may occur an increase in temperature up to a height of two hundred to four hundred feet, and then a fall, reaching the surface temperature at about two thousand feet elevation, unless the ground be wet, or the location be adjacent to a considerable body of water.

A Cloud Covering Cools by Day and Warms by Night. One of the principal functions of clouds is to conserve the heat of the sun. A covering of cloud, fog, or dense haze may not only screen off the heat of day, but greatly retard the lowering of temperature at night by reflecting and radiating back to the ground much of the heat that it has lost.

The Temperature of Oceans, Lakes, and Rivers. The same quantity of heat falling upon different kinds of matter produces different temperatures, depending on the capacity (specific heat) of each kind of matter to absorb or hold heat; this is notably apparent when the matter is land, water, or air; for the same quantity of heat will raise the temperature of a water surface only about one fourth as much as it will a land surface. Water rejects by reflection a considerable amount of the solar rays that fall upon it, while land reflects but a small part; and of that which is received upon the top layer of water

much is rendered latent in the process of evaporation and does not impart warmth to the water. Solar rays also penetrate water to a considerable depth and are quite uniformly absorbed by the whole stratum penetrated. These conditions cause large water surfaces and the air immediately over them to have a much lower temperature during the day and a much higher temperature during the night; and also lower temperatures during summer and higher temperatures during winter, than occur over a land surface of the same latitude.

Fresh Water and Salt Water Have Different Freezing Temperatures. In the ratio of 93.5 to 100 the specific heat of sea water is less than that of fresh water. Sea water is a better conductor of heat, so that it penetrates to a greater depth in salt water in the same period of time than it does in fresh water. Sea water regularly contracts with falling temperature until its greatest density occurs at four degrees below freezing, when it becomes solid ice and expands in the process of freezing; otherwise it would not float.

A Wonderful Phenomenon. In this respect a most wonderful and unexplainable phenomenon occurs with regard to fresh water. Not only sea water but practically all other forms of matter — liquid, solid,

and gaseous — expand with increasing heat and contract with decreasing heat, except fresh water between 39° and 32°, which actually expands with falling temperature. It seems as though the Creator had gone over His work and made revisions and corrections here and there, for unless the law with regard to the contraction of liquids with falling temperatures had been reversed for fresh water between 39° and 32° our rivulets, streams, lakes, and rivers would freeze from the bottom upward and the life of inland water be wholly or partly destroyed.

Even more calamitous would be the floods of springtime, for melting snows and falling rains would spread over and erode the cultivated fields of the husbandman instead of being carried away by the open channels of streams, as is largely done now.

The Freezing of Fresh and of Salt Bodies of Water. The freezing of water does not take place upon the surface of water only, as many suppose. Congelation takes place about millions of minute atoms of matter carried by the water in suspension. Water expands in the process of freezing and each particle of ice, no matter in what part of the body of water it is formed, immediately rises to the surface because of the gain in its buoyance as it changes from the liquid to the solid form.

When the surface of water cools by radiation to a cooler air it gains in specific gravity and sinks and warmer water comes up to take its place and in turn be cooled and sink; thus a circulation is established which continues in fresh water until every part of the body of water has fallen to 39° and in salt water to 28°. At these temperatures the two waters reach their maximum density. With the further cooling of salt water particles of ice form and rise to the top, as already described. With the cooling of fresh water below 39° the law that holds good for all higher temperatures is reversed and expansion of volume begins, which continues until 32° is reached. Therefore, fresh water of any temperature between 39° and 32° may float upon water that is considerably warmer; in fact, it has less specific gravity at 32° than at 46°. At 32° that which was a liquid becomes a solid and still further suddenly expands its volume.

The Cold of Ocean Bottoms. Few have any idea of the enormous volume of cold water that lies upon the surface of the earth, three fourths of which is covered with oceans whose depths average two miles and in many places are five miles. Below one mile in depth these oceans are always at about the freezing point of salt water, which is 28°,

except in the tropics, where it is but little warmer, varying between 34° and 36°.

How Temperatures of Inclosed Seas Differ from Those of Oceans. We will take the Red Sea as an example. It is 180 miles wide and extends in a nearly north and south direction for 1450 miles, about one half of it lying within the tropics. Evaporation takes place at a rapid rate, but only the surface water of the Indian Ocean on the south is able to enter to take the place of that which is lost, for a bar or sill at the entrance, extending from the bottom to within twelve hundred feet of the surface, separates the deep water of the sea from that of the outside ocean. Its surface temperatures vary about as the Indian Ocean, being 85° in summer and 70° in winter. Both bodies of water decrease in temperature at about the same rate down to the level of the sill, where the temperature remains constant the year through at 70°. Here a marked difference occurs, for the sea, which has a depth of 7200 feet, maintains the same temperature of 70° all the way down to the bottom; while the ocean continues to decrease in temperature down to a depth of about six thousand feet, where a temperature of 34° to 36° prevails throughout the year. A similar condition exists

with relation to the Mediterranean and the Atlantic Ocean. At the top of the sill, which is 1140 feet below the surface, the temperature of both bodies is 55°, and this degree of heat is maintained all the way down to the bottom of the Mediterranean, while in the Atlantic Ocean, at the same depth as the bottom of the Mediterranean, the temperature is only 35°.

How the Temperature of Water Changes with Latitude, Season, and Depth. It is impossible to name a given temperature as prevailing over bodies of water at all places on the same parallel of latitude, because ocean currents soon move water heated in one latitude to a higher or a lower position. At the equator the surface temperature is between 82° and 84°; it changes less than one degree between day and night, and not over five degrees between winter and summer; and below twenty-four hundred feet there is no difference between the seasons, the daily variation ceasing at less than a hundred feet. Below six thousand feet the temperature is always near the freezing point of fresh water.

In the middle latitudes the surface variation is from 50° in winter to 68° in summer.

At latitude 70° N. the surface temperature has but a small daily variation, and a yearly range of

from 35° for winter to 45° for summer; at a depth of twenty-four hundred feet it remains steady at 32°.

From this level there is a gradual decrease to a depth of six thousand feet, where a constant temperature of 28° exists, and below this there is no change. The temperature of Lake Superior decreases down to a depth of two hundred forty feet, where a temperature of 39° continues throughout the year, as it does downward for the remainder of the distance to the bottom, which has an average depth of nine hundred feet.

Direction of Wind Affects Shore Temperature of Water. Onshore winds skim off the warm surface water and drive it shoreward, where it banks up, and, pressing downward, causes the colder water beneath to flow back seaward. In like manner, offshore winds blow off the top water near the shore and send it out to sea, and colder water rises to take its place.

Great Heat of the Earth's Interior. We are ignorant of the conditions of matter under the heating effect of the enormous pressure that exists near the center of the earth, but it is probable that pressure prevents it from changing from a solid to a liquid or a gaseous form. The surface of the

solid earth rises to a much higher temperature as the solar rays fall upon it than does a water surface, or the air immediately above, because it is a poor reflector, a poor conductor, and a poor radiator, and when dry does not get any cooling effect from evaporation. Solar heat ceases to be apparent at a depth that varies with the latitude and the conditions of the soil with regard to moisture and specific heat, but everywhere at less than fifty feet.

At the poles and for some distance away the earth is covered with ice or snow the entire year and is frozen to a considerable depth. In the interior of Siberia and some parts of Alaska only a thin stratum of soil thaws out under the heat of summer. Beginning at about fifty feet, there is an increase of temperature downward, but it is not the same for all places, varying from a degree for forty feet to a degree for one hundred feet. Taking the average of the increase with depth, water would boil at ninety-five hundred feet and the hardest rock be molten at thirty miles. At a depth of 3490 feet near Berlin, the temperature was found to be 116°, while it was only 108° at the same depth at Wheeling, West Virginia, and in both places there is no change from day to night or from winter to summer.

Soil Usually Warmer Than Air Next Above. In summer, June to August, the bare, dry, top soil is warmer than the air ten feet above during all hours of the day and night, at times the difference being as much as forty degrees at midday. During winter, December to February, it is slightly cooler, except between 9 A.M. and 3 P.M. when the excess is seldom more than ten degrees. Evaporation from a wet soil lowers its temperature below that of the air immediately above through the rendering latent of a large quantity of heat. A melting snow surface also is below the temperature of the air because of the heat employed in changing the snow to the liquid form.

Let Mother Earth Cool and Refresh You During the Heat of Summer. How little the average man realizes the possibilities for improving his condition that lie close at hand. He does not know, or he is indifferent to the fact, that only three feet from the surface of the ground it is as cool at midday as at midnight, and that there is no diurnal variation in temperature below that depth, and no annual variation below a depth of from thirty to forty feet. If one were to set down the temperature of each day, add the numbers at the end of the year, and divide the sum by 365 the quotient would equal the tem-

perature always found at that place at a depth of about thirty feet. The temperature of a deep-flowing spring is always about the mean annual air temperature of the place. Here is health-giving coolness for summer and warmth for winter of which one takes little heed and derives practically no profit.

Remarkable, is it not? And these beneficent conditions are universal and available for all, except to those crowded into congested centers of population. The temperature is 54° in the Mammoth Cave in Kentucky and shows no change from day to day and from winter to summer.

During the extreme heat of summer and the cold of winter many could profitably, healthfully, and pleasantly live below ground. During such periods the cellar of the house, which should be deep and spacious, even extending beyond the dimensions of the edifice above, if a continuous supply of pure air could be forced through it, or natural ventilation accomplished by the plan outlined below, should be the lounging, resting, and sleeping place of the occupants of the household. It is not impossible or extremely difficult to change the stagnant, moist, germ-laden, ill-smelling air of the average cellar, in which it is positively dangerous to spend much time, into active, pure, and delightfully healthful air, —

air in which the worn and weary worker from the heat of the farmer's field, or the artisan and the clerk from the debilitating temperatures of the factory and the office could recuperate from the toil of the day, and from which they would go forth each morning invigorated for another day's efficient service, instead of dragging weary limbs from hot, sleepless beds, each morning less in energy than the day before. As is shown in other parts of this book, the researches of Huntington have proven conclusively that man is at his lowest physical and mental points of efficiency, and more subject to the contraction of disease through weakness, in midsummer and midwinter, and that the hotter the summer and the colder the winter the less is his energy and the lower is his power of resistance.

The whole problem is one of ventilation. While this is simple, it must be scientifically done. The ideal location for a living cellar is a hillside. It is easy to install ventilators in the roof of a cellar no matter where located, but these are of no avail whatever if there is not adequate air drainage at the bottom of the cellar. From the cellar in a hillside a conduit can lead from the bottom of the inclosure and have its opening at a lower level, thereby accomplishing drainage and circulation, which are

all-important in the creating of a sanitary condition of air under the cool earth. For each thousand cubic feet of cellar space there should project from the roof, to a height of at least six feet above ground, a separate ventilator shaft of at least one square foot cross-section dimension. A like ventilating capacity should be provided from the bottom outward to a lower level, but here two or more shafts may be combined in one, so the proper capacity is secured. During the day the draft will be upward through this system. But at night, except when the wind is brisk, the direction of movement of the air is reversed, and the cool air of the minimum temperature of night or early morning, because of its greater density, drops down into the cellar. The drainage shaft should be provided with a damper, which should be closed in the early morning, about daybreak, entrapping the cold air of night. The lower opening should be covered with wire netting, to exclude small animals, and the whole construction be of concrete, rendering it imperishable and rat-proof.

Inexpensive but Efficient Cold Storage. Such a sanitary cellar as described above provides an excellent storage for fruits and vegetables, comparing favorably with the much more expensive

artificial refrigeration. By an intelligent manipulation of the damper in the lower shaft, cool storage may be provided for fruit and other produce in the early fall, and protection secured against the extreme cold of winter.

Why Does Air Cool with Ascent and Heat with Descent? If a mass of air be elevated 183 feet it will be found to have lost one degree in temperature, because there is less air above to exert pressure upon it and it therefore expands to greater volume, and in the process of expansion work is performed which employs heat and renders it latent. One minute, one hour, or a thousand years thereafter, if this same air be lowered to its former elevation, it will be compressed into its previous dimensions and the heat energy that formerly was employed to expand it will be restored to the sensible condition. This ratio of 183 feet to one degree does not hold for any extended movement, because, as soon as the dew point of the air is reached, condensation in the form of cloud or rain occurs and the heat of condensation is released; that is to say, the same quantity of heat employed to create the water vapor at some previous time and thereby rendered latent is now become sensible and partly makes up for the loss by expansion as the air ascends. The

average is therefore about three hundred feet for one degree.

Height of Freezing Cold in the Free Air. The frost level remains constant, winter and summer, over the equator at about eighteen thousand feet. Elsewhere this level rises and falls with the seasons, the amplitude of the movement increasing with latitude and being greater over land than over water on the same parallel.

Daily Range of Temperature in the Free Air. The difference between the temperature of day and that of night decreases with altitude in the free air and ceases at about eight thousand feet. It is greatest during clear weather and least in cloudy weather. Narrow valleys may show a greater daily range than hilltops. When the sky is clear, radiation from the hillsides may heat the air in a valley to almost furnace heat at midday, while at night the air, coming in contact with cool vegetation higher up, chills and, gaining in weight by contraction, flows down and collects in the valley, making the bottom of the valley warmer during day and colder during night than the air above. Often moisture-laden winds precipitate much of their water vapor as the air cools by expansion in passing over a mountain range. These winds

carry a comparatively dry air over to the leeward side of the mountain, where the daily range of temperature will be much greater than on the windward side at the same elevation. San Francisco, where the prevailing winds come from the ocean, has a less range than New York, where the predominating winds are from the land; but New York is influenced by its proximity to the ocean, for its range is much less than at Denver, in the interior of the continent. The range is less on the east side of Lake Michigan than on the west side, as it is with relation to all similar bodies of water.

Man Soon Adjusts Himself to Changes in Altitude. In Colonial days it was noted that horses coming down from the mountains in North Carolina ran swifter in the races the first day or two after changing to a lower level. In going to a higher altitude an increase in the number of red corpuscles in the blood enables it to absorb oxygen more readily, and thus compensate for the loss in the density of the air. Because of this gain in the chemical activities of the life current, one feels a marked increase in strength on coming to a lower level, but the gain lasts for only a short time before there is a readjustment to former conditions. Persons with weak hearts may not be able to live at an altitude of

four thousand feet, and most people experience inconvenience, at least, on first reaching ten thousand feet; but nature is accommodating, and a number of large cities prosper at altitudes of from one to two miles.

CHAPTER XI

HOW CLIMATE IS MODIFIED AND CONTROLLED

If the surface of the earth were all land, and the axis of the earth's rotation were perpendicular to the plane of the earth's orbit, the day and the night would be equal everywhere, and there would be no seasons. There would be no wind, for the friction of the air against the rotating earth would soon cause all levels of the atmosphere to take up the exact easterly velocity of the solid body below. The atmosphere would be contracted by cold and drawn downward so as to have less depth at the poles than at any place having latitude, and it would be deepest at the equator, where the direct rays of the sun would expand it to an altitude of probably twice what it could have at the poles. Centrifugal force — the force that causes mud to fly off the rim of a swiftly rotating wagon wheel — would further lower the height of the atmosphere at the poles and cause it still more to extend outward

at the equator. The atmosphere would soon adjust itself to these constant conditions and forces and thereafter remain at rest relative to the earth. There would be no life, for there would be no vaporous atmosphere if the surface all were without water. There would be extremely little heat to disturb the atmosphere with motion, for the dry gases of the atmosphere are practically diathermanous, and the heat of the sun would pass out by radiation from the burnt and parched surface of the earth during daytime without imparting more than a minute fraction of its energy to the atmosphere; and at night the thin surface of the top soil that had been heated to a furnace temperature during sunshine would be quickly locked in the fastnesses of intense cold — probably 200° below zero.

If we now incline the axis of our imaginary earth 23½°, we shall introduce seasons whose only change, the one from the other, will be in the duration of sunlight, as there is no water vapor to absorb and utilize the sun's rays in the initiation of motion and the creation of storms. We are assuming that there would be enough heat absorbed to prevent the atmosphere from liquefying, which it would do at any temperature lower than 312° below zero. If the temperature were to fall below the liquefying

point of air, we would have the singular phenomenon of the air expanding to a gas during daylight and condensing to a liquid during nighttime, and, of course, that would mean motion and winds, but of such a nature that one would hardly dare speculate as to their peculiarities.

We introduce these hypothetical cases for the purpose of conveying a clearer idea of the overlapping of conditions and the combinations of forces that influence and control the seasons, the climate, and the weather of the earth.

If the surface of the earth were all water and its axis perpendicular to the plane of its orbit, the day and the night would everywhere be equal and there would be no seasons. With a water surface there would be an atmosphere nearly if not quite saturated with vapor of water, in other words, of practically one hundred per cent. relative humidity. It is doubtful if either animal or vegetable life could exist; the first would die of internal heat, because a saturated air would permit of no cooling by evaporation from the pores of the skin, or from the tongue and mouth of animals that do not perspire; and the second could not grow without the chemical action of sunshine, which is a necessary part of the laboratory of the leaf of every growing plant, the sunshine acting upon the green

granular matter which constitutes the chlorophyll of the plant. There would be little difference between the temperature of day and of night — probably not more than one degree. As the earth would everywhere and at all times be covered with a deep stratum of cloud there would be little loss of heat to space by radiation and the temperature would be excessive, rising in the tropics to near the boiling point. We will assume that the atmosphere would reach a stable and unchanged condition of great heat and humidity and be without motion or precipitation.

If now we incline the axis of this water-covered earth and introduce the complication of seasons, we shall not only have variation in the hours of sunshine, increasing as we go from the equator toward the poles, but, the capacity of air for moisture being less and less with falling temperature, we shall have downpours of rain as the summer slowly merges into fall and the latter into winter. Although the air will be saturated, there probably will be no rainfall from the time when the temperature begins to rise after midwinter until it reaches and passes the maximum heat of summer. It is fair to assume that during the rainy period there will be cyclonic storms with torrential precipitation, and

that the anti-cyclones that are a necessary concomitant of cyclones, while they may cause a temporary cessation of precipitation in the area that they cover, by the dynamic heating of the air in their downward motions, will be ineffective in fully clearing away the clouds from a water-covered earth. It is doubtful if such an earth would be suitable for life, — certainly not for man.

The Real Earth of Land, Water, and Inclined Axis. The different manner in which land and water surfaces absorb, radiate, and reflect the heat from the sun has a profound influence on climate, which also is modified by latitude, elevation above sea level, elevation above a valley or above a surrounding plane, direction of wind, height and trend of direction of hills and mountains, the position of lakes and inland seas, the relative position and magnitude of continents and oceans, storm tracks, and ocean currents.

Influence of Continents and Oceans on Climate. Charts 1 and 2 (pages 99 and 100), constructed from observations taken on ships and on land, for a long series of years, show certain Highs and Lows of vast extent, sometimes called "Centers of Action", because they do not travel across continents and oceans, as do the migrating Highs and Lows that

cause weather. Rather do they slowly reverse their relative positions between winter and summer. Continents cool by radiation in winter more rapidly than do oceans; the air contracts, settles down and grows denser and air flows in at the top from the oceans and outward at the surface of the earth toward the oceans; thus is built up the winter Highs, or centers of action, on continents. Continents heat up by absorption in summer more rapidly than do oceans; the air expands, rises, and flows away in the upper levels to oceans and flows in at the bottom from the oceans; and thus are the Lows, or centers of action, established on continents in summer. It is apparent that these processes must be reversed for the oceans, and that the Highs will be found there in the summer and the Lows in the winter. Carefully follow the illustrations of these principles by examining the whole region north of the equator on Charts 1 and 2.

In the Southern Hemisphere there is not such a pronounced shifting of the Highs and the Lows from oceans to continents and back again, with change in the seasons, as there is in the Northern Hemisphere, because of the small area of land in comparison with that of water; but in the midst of the southern summer, which occurs in January (Chart 2), Lows

are shown over South America, Africa, and Australia. Note how the winds blow out of all the Highs and into all the Lows. Also observe that the winds generally blow from about latitude 30° north and south towards the equator, due to the great heat of the tropics, which causes the air to rise and in the high levels to flow northward and southward, settling down to the earth again through the belts of high pressure that irregularly encircle the earth at latitudes 30° north and south.

In the interior of continents the temperature falls lower at night and rises higher during the day, and falls lower in winter and rises higher in summer than on any of their coasts. On the coast of central California, for instance, the ocean is so cool in summer and the winds blow so steadily from it that the thermometer ranges between 55° and 70°, even when there are temperatures of over 100° but a few hundred miles away in the great interior valleys, or on the broad plateaus of the mountains. New York and Boston, in nearly the same latitude, also have their summer temperatures modified by ocean influence, but they are on the east side of a broad continent, where the prevailing westerly winds give to them more the character of a continental climate than one marine; but occasionally the east wind, for a

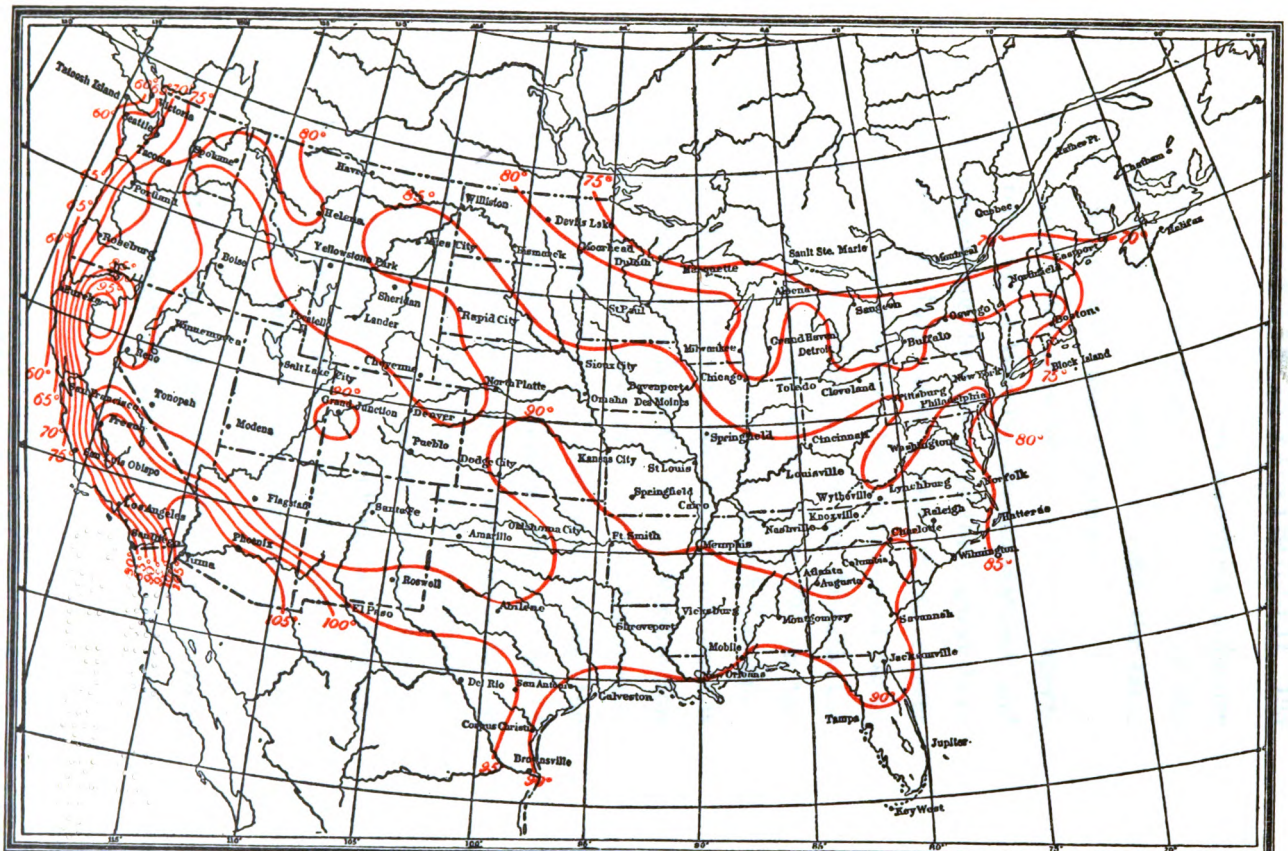


CHART 12. — AVERAGE MAXIMUM TEMPERATURE FOR JULY (Henry).

short time, gives to them the modifying influence of the ocean. In the winter the influence of the oceans is to modify the extremes of cold, the same as they do the excessive heat of summer.

Chart 8 (page 129) showing the lowest temperatures ever recorded at Weather Bureau stations, and Chart 12, presenting the average of the highest daily temperatures of July, graphically show, clearer than any text can describe, the influence of continents and oceans on climate. On the Atlantic the average maximum of day varies from 70° on the Maine coast to 85° on the coast of North Carolina; while on the Pacific, where the marine influence is stronger, the average is from 65° on the Washington coast to 80° on the coast of southern California. But near the center of the United States where the continental influence predominates, the average of the highest daily temperatures varies from 85° to 90°. On Chart 8, showing the lowest temperatures, the line of 20° below zero passes through Boston, southwest to Chattanooga, west to Flagstaff, Arizona, and then irregularly north to Seattle, showing the influence of both oceans in carrying the line northward.

Because of the vast extent of the Eurasian (Europe and Asia) continent the difference between conti-

nental and marine climates is more marked than in the Western Hemisphere. Huntington and Cushing, in their splendid work on "Principles of Human Geography",[1] make a comparison between the southern Lofoten Islands, off the coast of Norway, and Verkhoyansk in Siberia, which probably furnish the greatest contrast to be found anywhere between places of the same latitude. Although both are inside the Arctic Circle, the influence of the Atlantic Ocean with its warm-water currents coming all the way from the tropics (Chart 13) protects the Lofoten Islands from the extreme cold that otherwise would come to them; vegetation remains green and cattle are pastured every month in the year. But the ocean retains nearly the same temperature in summer as in winter, and as a result the Islands are too cold to grow trees or many crops. Verkhoyansk is so different that one can scarcely believe that both places are in the same latitude. At the Siberian town the winter temperature falls to 70° or 80° below zero every winter, and has been known to register 90° below zero. It is said that steel skates often will not "take hold" but slip sideways as well as forward on the surface of the excessively cold ice. This doubtless is due to the fact that under

[1] John Wiley & Sons, New York.

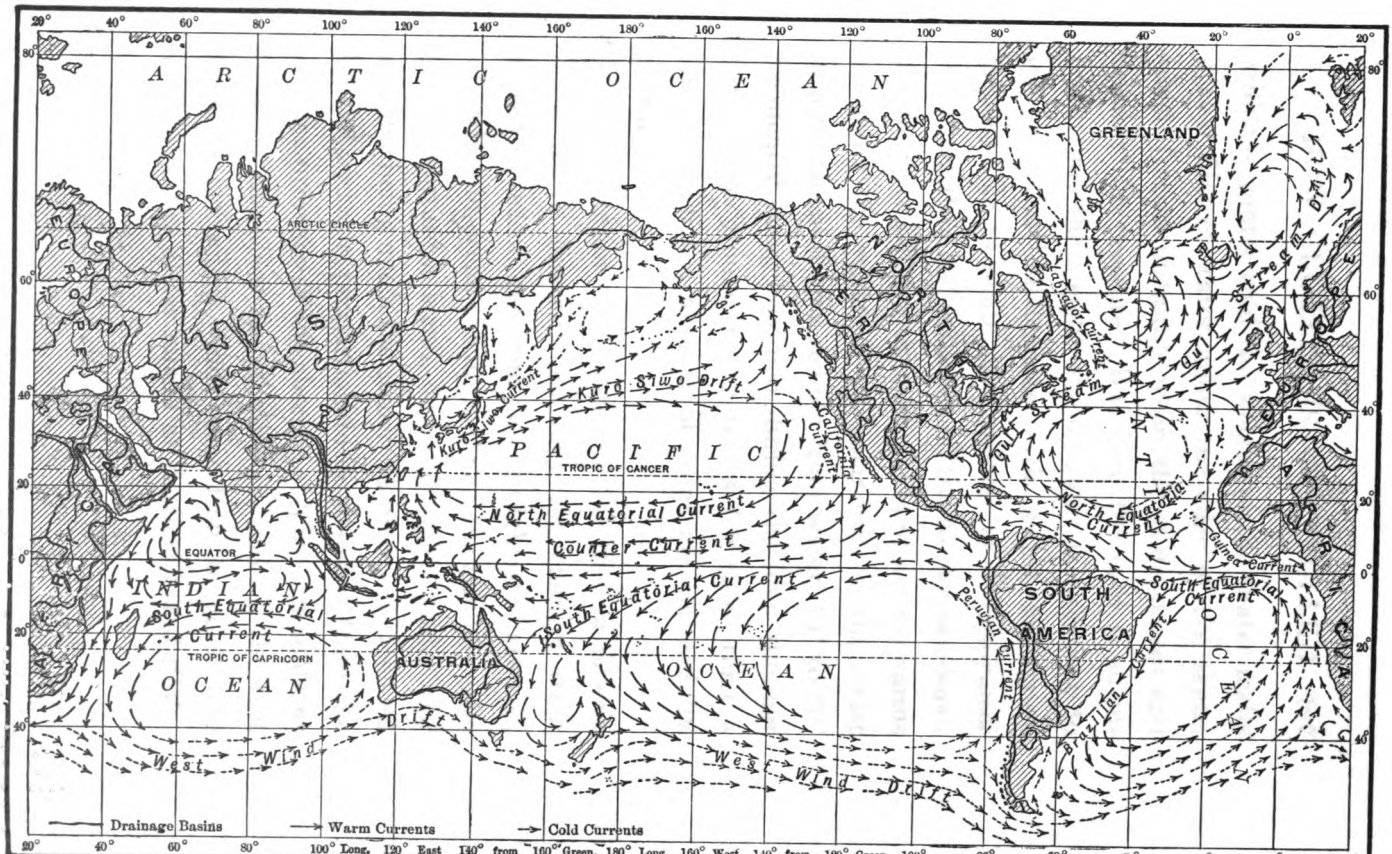


CHART 13. — OCEAN CURRENTS.

ordinary winter cold the weight of the skater melts a thin film of water under the edge of the skate, which freezes instantly when the skate passes and relieves the pressure. But here the cold is so intense that the weight of no skater is sufficient to lubricate his movements with water molecules. Remarkable to relate, the summer at Verkhoyansk is warmer than in the islands off the Norwegian coast, due to the rapidity with which the land surface warms up under the action of the solar rays in the midst of a continental area remote from water, 75° to 80° frequently being recorded during the long summer days. The ground never thaws for more than a foot or so, but a number of crops are successfully grown.

In the interior of a continent like that of Siberia or of North America not only the changes from season to season but from day to night are extreme; while in mid-ocean the diurnal and the annual range of temperature is small, day and night, winter and summer being much the same. A place is influenced by the ocean in proportion to its distance from the sea, the presence or the absence of hills or mountains between the place and the water, and by the fact that the prevailing winds come from or go to the ocean. Cities as far inland as Baltimore and Phila-

delphia have their extremes of temperature somewhat modified by the Atlantic Ocean, and if it were not for the Coastal and the Sierra Nevada Mountains the influence of the Pacific Ocean would be felt at least as far inland as Denver, and the great Rocky Mountain plateau would be one of the garden plots of the world. The influence of the Pacific would reach inland farther than now does the Atlantic because of the prevailing westward drift of the atmosphere in all middle latitudes.

Exaggeration of the Forest Influence on Climate. Chapter XIII, on Change of Climate, shows more in detail the process whereby the sun lifts up the water vapor from the Gulf of Mexico and the Atlantic Ocean and how cyclonic storms draw this vaporous atmosphere northwestward far into the interior of the continent, the Alleghany Mountains not being high enough to offer serious obstruction.

The writer would again caution the reader not to be misled by any pseudoscientist, no matter how worthy his purpose may be, who would teach that the operations of men in changing forest areas to cultivated fields, gardens, villages, and cities, has in the slightest degree harmfully affected the climate, or augmented floods or intensified droughts. A field of grass, of wheat, of corn; an orchard of

fruit; a highway bordered with towering, majestic oaks and elms; or a grove of cultivated trees about a prosperous home is just as beneficial to the climate as the thickest and most impenetrable forest and far more pleasing to the eye and helpful to mankind. Forests should be protected, conserved, and grown because we need timber, not because a lot of foolish people are writing nonsense about them.

Influence of Lakes and Rivers. With the exception of contributing to the formation of occasional fogs over their surfaces and the adjacent low lands, through the rising of warm water vapor into the cold air that often collects at the bottom of valleys during nighttime, rivers exercise little influence on climate. Lakes exert a modifying influence on the temperature of places near their shores but only for a few miles therefrom, and they are too small to exert any appreciable influence on rainfall. If one examine charts showing the average rainfall for the United States by seasons, he will observe that the amount gradually shades off as the distance from the Gulf or Ocean increases, without any relation whatever to the five Great Lakes. Deserts exist on either side of the Caspian Sea, although it slightly increases the rain of the Elburz Mountains to the south. If these great

bodies of water do not influence the rainfall, how ridiculous to assume that the changing of forest areas to other forms of vegetation possibly can affect precipitation or influence droughts. Stress is laid on the fact that some land is left bare and then is eroded into deep gullies. This is true, but the fault is one that may be corrected by a proper system of plowing and cultivation. And at most the area so eroded is so infinitesimal in comparison to the vast regions changed from forests to growing crops as to be negligible.

Influence of Ocean Currents on Climate. Climates are markedly influenced by the currents of oceans. Charts 15 and 16 show the normal wind circulations of the globe; note that the centers of the great swirls are coincident with the location of the High and the Low centers of action located on Charts 1 and 2. Next observe Chart 13, showing the ocean currents, and it will be seen at once how closely the circulation of the great ocean currents follows that of the winds, due to the friction of the air upon the water, and to the interposition of bodies of land that turn about or deflect the currents.

Water has a greater capacity for heat than nearly any other substance. It requires ten times the quantity of heat to raise a pound of water one de-

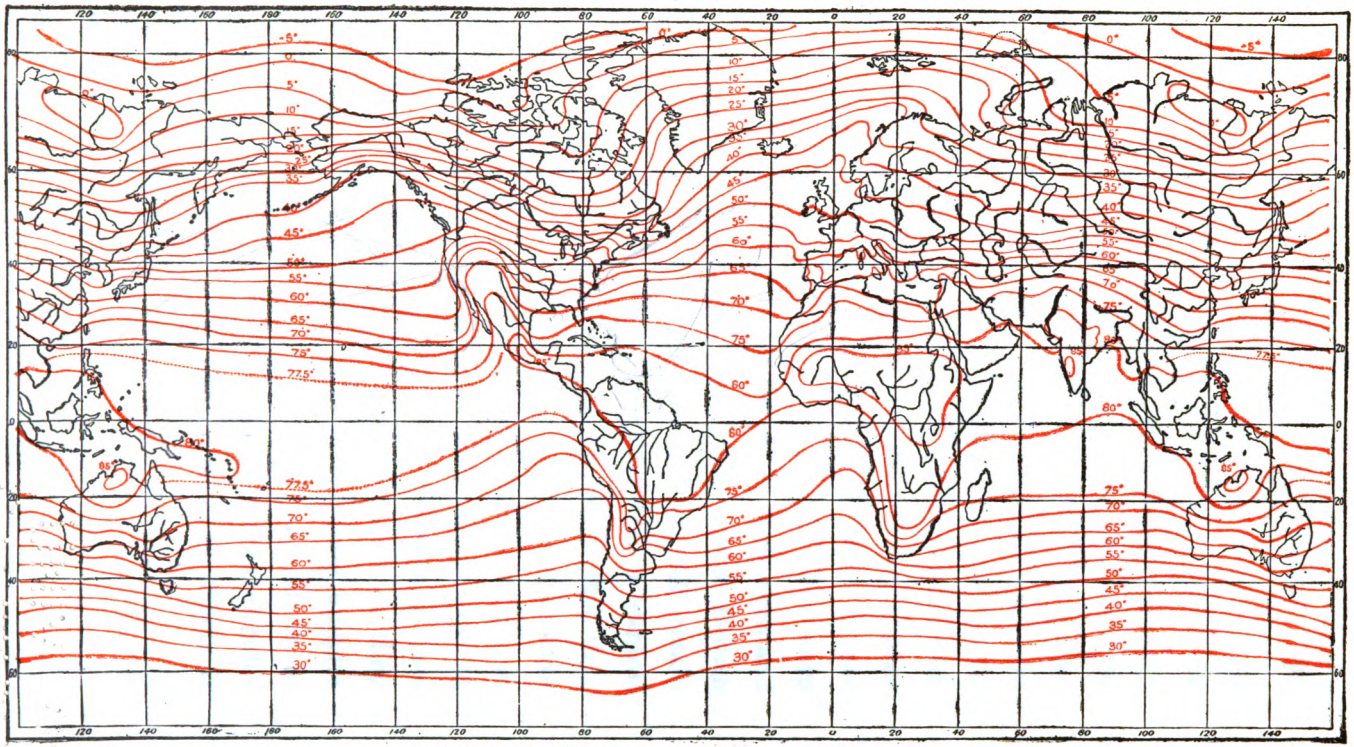


CHART 14. — MEAN ANNUAL ISOTHERMS (Buchan).

gree that it does a pound of iron. The oceans therefore store up vast quantities of the heat of the sun and, unlike the continents, distribute this heat northward and southward without regard to latitude. Much of the heat of the tropics is thus transported far northward and southward from the equator. The extensive eddy-like circulation of the south half of the North Atlantic Ocean sends currents northward along the coast of the United States which set eastward at latitude 40°. A part of these reach the coast of Spain and then turn south; the greater part spread out in mid-ocean and move northeast, bathing the coasts of the British Islands, Iceland, and Norway. They still retain some of the heat that they absorbed from a tropical sun, and they therefore give to the coasts that they reach a higher temperature than they would have if the ocean waters were moving from the north, or than they would have if there were no currents at all. On Chart 14 note how the isothermal lines are carried northward by these currents as they cross the Atlantic Ocean. The Gulf Stream mingles with these northeast currents but adds little to their temperatures, for the general ocean circulation would produce practically the same effects if there were no Gulf Stream.

Follow the currents down the coast of Spain and of northeast Africa; then note on Chart 14 the southward trend of the lines of equal temperature, as the currents bring colder water southward to cool the air. Next examine the currents of the Pacific and the isothermals. The currents moving northward towards the equator along the west coast of South America, and those moving southward, also toward the equator, along the west coast of the United States and Mexico cause a bulging of the isothermal lines from the positions that they would occupy if there were no currents coming from colder regions.

Influence of the Gulf Stream on Climate. From either side of the equator the surface winds (Charts 15 and 16) blow the water westward, causing what are known as the "Equatorial Currents" (Chart 13). The eastward projection of the coast of South America divides the Atlantic equatorial current into two parts; one goes south along the coast of South America and sets up the circulation in the South Atlantic, which sweeps north along the southwest coast of Africa. The other passes to the northwest, a part setting up the North Atlantic circulation and the remainder sweeping through the Windward Islands and storing itself in the Gulf

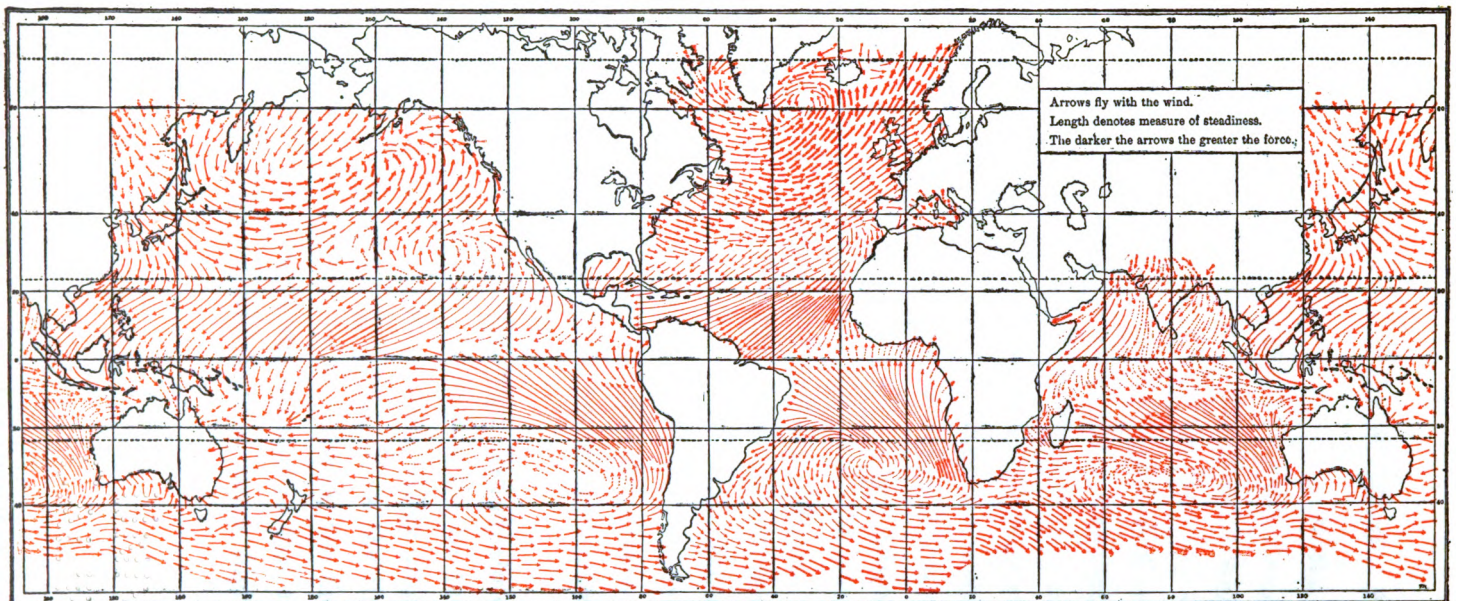
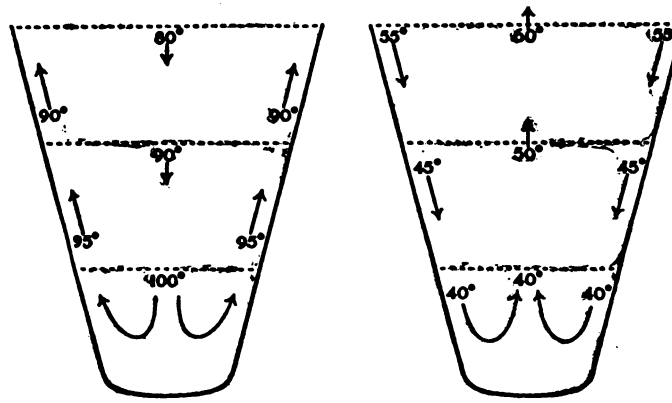


CHART 15. — NORMAL WIND DIRECTION AND VELOCITY FOR JANUARY AND FEBRUARY (Köppen).

of Mexico, whence it is driven out at a velocity of some five miles per hour through the narrow channel between Key West and Cuba. Here it has a depth of half a mile and a width of forty miles. Its velocity is accelerated because it enters the Gulf in a broad sweep and passes out through a constricted channel. It retains its individuality as a warm river passing through the ocean because of its greater velocity and higher temperature than the waters in which it finds itself soon after it leaves the Gulf; but it gradually merges with the great Atlantic circulation as it passes to the middle of the ocean. It is the opinion of the writer that its influence on climate has been exaggerated, that the warming of Europe that is credited to the Gulf Stream is accomplished by the mere presence of the ocean to the westward and to the general circulation of that ocean without regard to the wonderful phenomenon known as the Gulf Stream.

Effect of Valleys on Day and Night Temperatures. Valleys affect temperatures in proportion to their depth and width. A deep, narrow valley might have the effect illustrated by Figure 27, if the time were summer and the sky clear. During the daytime radiation would warm the interior so that the bottom of the valley would have a much higher

temperature than the free air at the top of the valley, and the movement of the air would be sluggishly down the center and up the sides of the depression.



Summer day temperature in a narrow valley.

Summer night temperature in the same valley.

FIGURE 27.

During nighttime all the conditions would be reversed. Vegetation, losing heat by radiation much faster than the air, would cool the latter as it came in contact with the sides of the valley. The air would slowly descend along the sides through gain in specific gravity and collect at the bottom with a temperature much lower than it had when it started its descent.

Effect of Mountains on Climate. The rarity of the atmosphere of mountains readily allows the rays of the sun to pass through it and thus the sur-

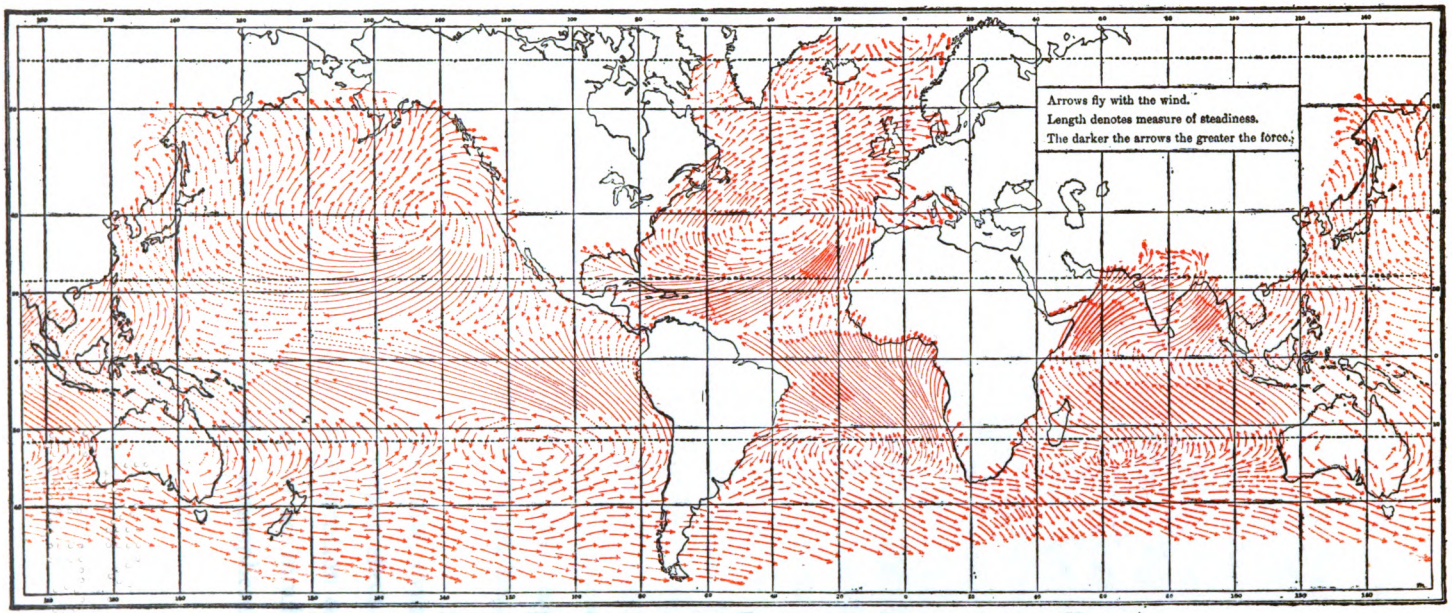


CHART 16. — NORMAL WIND DIRECTION AND VELOCITY FOR JULY AND AUGUST (Köppen).

face of mountains is quickly warmed, but the same conditions permit a rapid radiation at night, so that there are considerable extremes of temperature. Air cooled by contact with a mountain may flow down its sides at night and collect in depressions below, often causing frost on still nights where the temperature higher up is much above freezing. Mountains may be more cloudy and rainy than plains, for the currents of air that cross them must rise, and in rising they cool by expansion and often reach the dew point of the air, moisture being precipitated in the form of clouds, rain, or snow. Often a peak is constantly capped with a crown of clouds. Mountains may intercept vapor-bearing winds from oceans, force them to such an elevation that their vapor is largely precipitated on the windward side of the mountain, and receive them on the leeward side as dry, rainless winds. Vast desert areas are often the result. A good example is presented in the case of the Pacific coast mountains and the desert plateau to the east.

Mountain peaks may be covered with snow, even though they be located in the tropics, if their elevation be sufficient. This is because the absorption of both incoming and outgoing radiation is so much greater in the lower reaches of the atmosphere,

where the water vapor is densest. Wherever observations have been made they have shown that the temperature of the air on high mountain peaks and crests and for a distance of one to three hundred feet above them is cooler than adjacent free air of the same height, due to upward deflection of air currents and their cooling by expansion, and to radiation from the peak.

The Himalayan Mountains exercise a profound effect on the climate of Asia. The monsoon (any wind that alternates annually in direction or force) of summer brings the moist air from the Bay of Bengal and precipitates torrential rains from it as it ascends to higher and higher elevations in passing over the great heights of the mountains. At a place four thousand feet above the sea and not distant from Calcutta, the annual rainfall is 466 inches, while the average for most of the region east of the Mississippi River is only forty inches. More than forty inches have been known to fall in one day in the Himalayan Mountains. As in the case of all very high mountains, the rainfall increases in these mountains up to a certain elevation and then decreases. North of the mountains the monsoon passes into the interior of Asia with withering dryness and vast deserts are the result.

Figure 28 graphically presents the average monthly temperature and rainfall of typical places in North

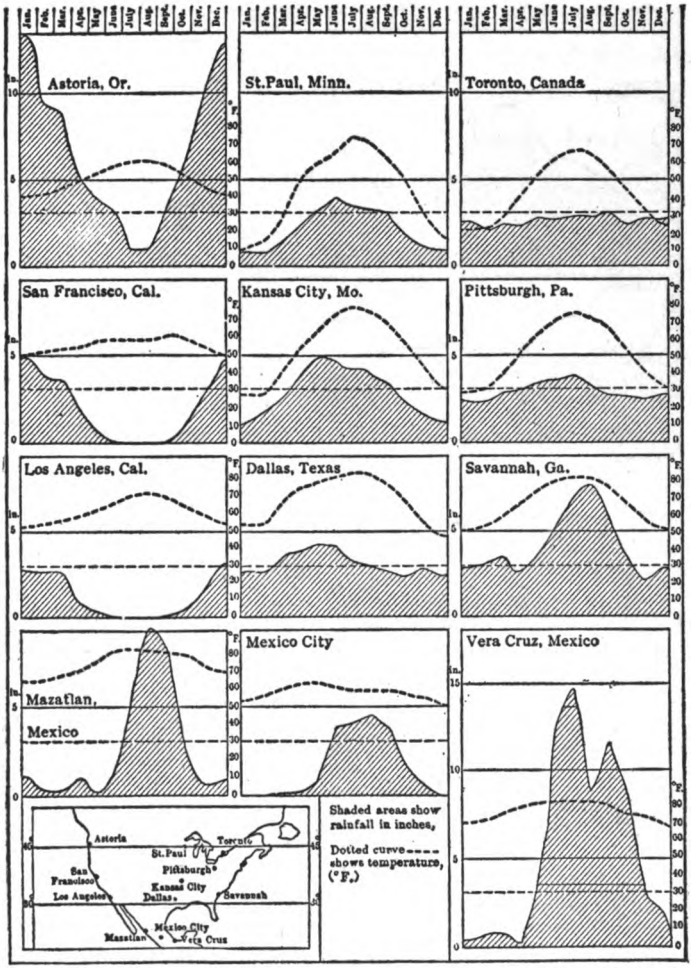


FIG. 28. — Average Monthly Temperature and Rainfall of Typical Places in North America. (Huntington and Cushing.)

America, and Figure 29 of places in the Old World. Here may be seen every phase of climate from tropi-

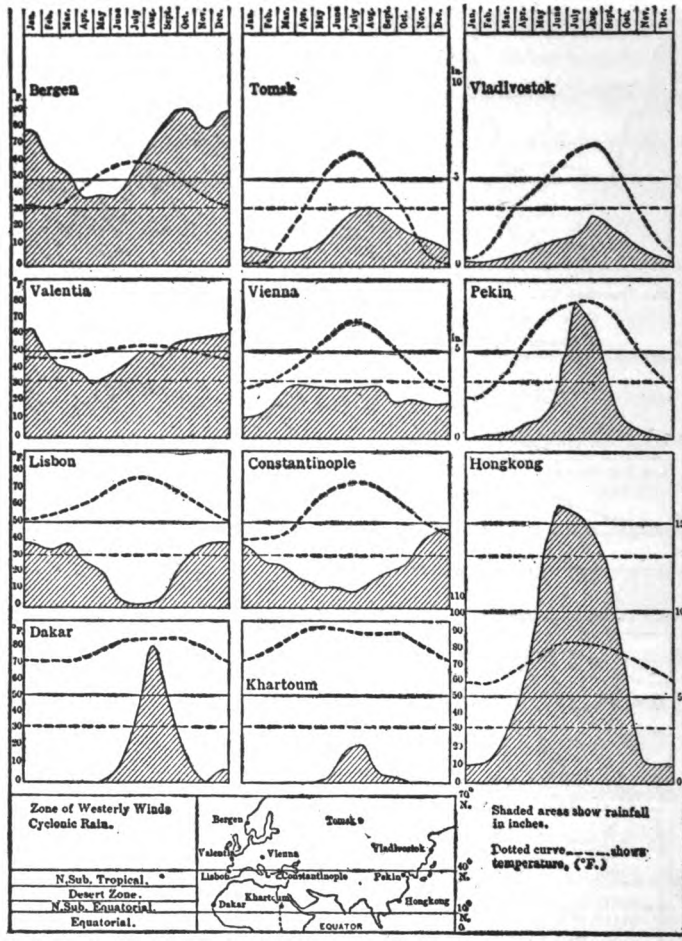


FIG. 29. — Average Monthly Temperatures and Rainfall of Typical Places in the Old World. (From "Principles of Human Geography." John Wiley & Sons.)

cal to temperate and to cold, and from marine to continental. By studying the winds on Charts 15 and 16 and the ocean currents on Chart 13, the reader should be able to find an explanation for the different conditions shown. For example: Mazatlan and Vera Cruz are both on the coast of Mexico, the first on the west and the latter on the east. Each has a rainy period in the summer, but at Vera Cruz the rain begins earlier and lasts later and is much heavier. The reason is that they both have north winds in winter (Charts 15 and 16), but in summer Vera Cruz receives winds direct from the Gulf of Mexico and at Mazatlan the winds continue to blow from the north, with but a slight inclination landward. Again, the explanation for the fact that Mazatlan has a monthly range of temperature from 60° in winter to 80° in summer, while Vera Cruz has a range of only 70° to 80° is found in the wind direction.

The City of Mexico is wonderfully favored by climate. Here a moderate rainfall occurs from May to September. The oceans are not far distant on either side, as distances are measured continentally, but its great elevation on a table-land relieves it of the torrential rains usual to the tropics; and yet it is close enough to marine influence so that its

air has not the nerve-irritating dryness of the plateau of the Rocky Mountains, and it has a remarkable evenness of temperature between winter and summer, with a monthly range between 50° and 60°. Its range between day and night is sufficient to be stimulating.

Still looking at Figure 28, note the remarkable similarity between the climate of Pittsburg and Toronto. Each has about the same rainfall and it is almost equally distributed throughout the months of the year. The only difference is that Toronto is a little colder. St. Paul and Kansas City, typical of the climate in the interior cities, have a small amount of precipitation in winter, considerable in summer, and a wide range of temperature; while the Pacific coast cities have dry summers, and winters that vary from three inches of rain at Los Angeles to fourteen inches at Astoria, with no excesses in temperature.

Temperatures Aloft in the Atmosphere. Kite and balloon observations have not been continued long enough, nor have they been made at a sufficient number of places, to give one the data from which the climate of any considerable altitude in the free air may be determined, but from a large number of free balloon observations made with self-recording

instruments, in the middle latitudes of this and foreign countries, Figure 1 (page 12) has been constructed, which shows the manner in which the temperature decreases with elevation up to eighteen kilometers (eleven miles). Note how rapidly it falls with elevation up to eleven and a half kilometers (about seven miles). This depth of air measures the thickness of the turbulent stratum in which cyclones and anti-cyclones operate. At its top the temperature always is about 64° below zero in winter and 70° below in summer. And right here occurs a most wonderful phenomenon, — one of which scientists were entirely ignorant less than two decades ago. At first it was thought that there was something wrong with the recording thermometers, for they failed to register falling temperature with gaining altitude after the storm stratum was passed at seven miles. Then it was noted that all instruments displayed the same peculiarity, and the " Isothermal Stratum " (equally heated region) was discovered, in which the temperature maintains the same degree of intense cold so far as exploration had been made. From Mount Weather, under the direction of the writer, a balloon was flown to nineteen and one tenth miles before it exploded and sent a parachute gently down to earth with its precious

record. This flight showed practically no change in temperature after the isothermal stratum was reached. (See Chapter III.) One is reasonably safe in assuming that there is no oxygen beyond an altitude of thirty miles and that at fifty miles the nitrogen becomes inappreciable, and that, therefore, the temperature must shade away to practically nothing when the void of outer space is reached, notwithstanding the presence of the newly-discovered isothermal stratum nearer the earth.

CHAPTER XII

CIVILIZATION FOLLOWS THE STORM TRACKS

THE MOST DOMINANT RACES — THOSE THAT BEST CO-ORDINATE THE MENTAL AND PHYSICAL FACULTIES — ARE FOUND TO EXIST UNDER CERTAIN CLIMATIC CONDITIONS — CHANGE THE CLIMATE AND YOU CHANGE THE MAN

In a climate where man needs little protection from the elements, where he may lie upon his back in the shade and with his bare toes pick wild growing fruit to nourish his body, one will find no great leaders in art, literature, science, statecraft, or industry; likewise, in the Arctic, where man simply gathers enough blubber to supply his animal wants and then burrows beneath the snows of fierce winters, one will not find leadership or creative genius. The regions of greatest human potential are limited to such portions of the temperate zone as have an abundance of rainfall, frequent changes in the weather, and an alluvial soil. In other words, the most perfect composite of human resourcefulness

is found where nature is neither so fierce as to crush human aspiration, nor yet so gentle as to lull human desire.

Humbolt says: "Man is the product of soil and climate; he is brother to the tree, the rocks, and the animals." We shall endeavor to show that civilization and the greatest human potential follow the storm tracks of the world, and that climate is the most important factor in his environment, for without its proper adjustment to his needs the richest soil and the most beneficent form of government fail to bring out the best that is in him. Empire is determined as much by direction and force of the wind and changes in the weather as by the scheming of politicians, the deep-laid plans of diplomats, or the marshaling of battalions.

The first thing that vigorous man requires is active atmospheric conditions and in his migrations he follows the climatic lines that appease his desires. A climate of little change between day and night and between winter and summer is soothing and at the same time deadening to the human faculties; but changes should be frequent rather than violent. The daring, the creative, the pioneering, the persistent spirits of mankind, like snow birds showering themselves with icy crystals, revel in the cool air,

the perpetual oscillations of temperature, and the frequent changes from sunshine to cloud that pertain to the regions where storms are most numerous.

Some days the mind works with a joyous lucidity, the spirits are high and the step elastic and vigorous. On another day the mind is turbid; it works slowly and hesitates in reaching decisions; one is listless and lacking in physical energy. On both days one may be in a perfectly normal physical and mental condition, except for the effects of the weather.

Under the direction of the writer, comparison of the records of crimes of violence with the weather records, by officials of the U. S. Weather Bureau, showed a marked increase of crime of this sort during midsummer as against midwinter, and the extremely hot summer showed more crime than the cool ones. During recent years Ellsworth Huntington has made exhaustive and extremely valuable studies of the records of piece workers in factories and elsewhere from New England and the Middle Atlantic States down to Florida and the Gulf of Mexico, and also of the mental activities of the cadets at West Point and Annapolis, and of the students in colleges, as shown by their recitation markings.[1]

[1] "Principles of Human Geography", Huntington and Cushing. John Wiley & Sons, New York.

He has compared these records with the weather day by day and hour by hour and definitely shown a direct relation between variations in the meteorological conditions and human efficiency. He finds that people's health and strength are greatest when the temperature falls to between 56° and 60° at night and rises to somewhere between 68° and 72° during the day. He has determined the optimum, or, in other words, the meteorological conditions best suited to man's health, happiness, and efficiency. For mental activity the optimum temperature is much lower than for physical. People's minds are more alert, they reason with greater analytic precision, they have greater confidence in their decisions and they are more optimistic, when the temperature falls to about freezing at night and rises to 45° or 50° during the day. Except for limited activities, the most efficient man is the one in whom the mental and physical faculties are most perfectly coördinated. Broadly speaking, this agreement may be best accomplished during times when the daily temperature ranges between 45° and 65°.

Excessive humidity in midsummer — eighty per cent. or over — is harmful and adds enormously to the death rate; on the other hand, some of the worst colds may come from extreme dryness in

summer. It may be found feasible to dry the air in sleeping and living rooms in summer when the humidity is too high, by closing the apartment and forcing the air over or through calcium carbide or melting ice and salt. When the air is kept at 65 to 70 per cent. humidity in winter one will feel comfortable in a much lower temperature — about 68° — than when the air is extremely dry, as it usually is in the average living apartment. With a relative humidity of 30 to 40 per cent. which one now often finds in warm houses in winter, the temperature may be forced up to 75° or over and still one may feel cold, because of the rapid evaporation from the pores of the skin, and the cold created inside the clothing by the heat lost in the process of evaporation. Bear in mind that perspiration is going on at all temperatures, even if one is unconscious of the fact.

In the most populous portions of the United States there are two periods of maximum efficiency and two of minimum each year. Let us consider that wonderful region including southern New England, the Middle Atlantic States, the Ohio Valley, and westward to the Rocky Mountains. Again referring to the records of Huntington we find that human energy is greatest in October; the output of factory, mine, and counting room is greater per man than at any

other time of the year and the product of mental effort is greater and of higher quality. Likewise disease is less and the death rate the least. From this time there is a loss in energy until January or February, when vitality and efficiency may have dropped twenty to thirty per cent. Then there is a gain until May or early June, when the conditions of health and efficiency are nearly equal to the most favorable time of the year in October. Again there is a loss until the middle of July, when a second minimum occurs; physical and mental energy are at a low ebb and the death rate is high. Diseases are not quite the same as in winter, as stomach troubles are more common than colds. The hotter the summer and the colder the winter the less favorable are the conditions of human existence.

As there is a certain optimum beyond which diurnal and annual range of temperature cannot increase without a loss in energy, so there is a limitation in latitude beyond which the favorable climatic conditions decrease as one goes northward or southward. As an example, Canada and northern Maine have but one unfavorable period, which is the entire winter. The people of these regions are at their greatest potential July to September, after which they show a steady decline as the

severity of the northern winter draws upon their vitality, until in January and February their minimum is below that of regions considerably farther south for the same period.

From the most favorable climatic area in the middle latitudes — and the entire world possesses none more favorable or of greater extent than that possessed by the United States — the loss of health and strength due to the enervating effects of heat, high humidity, and insufficient temperature oscillations increases as one goes toward the equator. In Florida and the southern third of the Gulf States there is but one favorable period, the short winter. The enervating conditions still further are manifest as one proceeds farther southward.

In the "Principles of Human Geography", it is stated that "in Central France and Southern Germany the seasonal variations in health and strength are much the same as in Boston, New York, Cleveland, and Detroit. That is, people are most healthy and strong in October and early November and again in May and early June, while they are weakest and most subject to disease in January, February, and early March, and again in July and August. Farther north, for example, in Scotland, Scandinavia, and Finland, the summer is the best time of the whole

year and the winter the worst. To the south, on the contrary, in Italy, Spain, and Greece, the harmful effect of the winter decreases and that of summer increases, until finally on the south side of the Mediterranean the winter is much the best time of the whole year, while the long summer greatly diminishes the people's efficiency and increases disease and death."

As the highest mental activity is coincident with temperatures lower than those that induce the greatest physical energy, it naturally follows that in the Ohio Valley, southern New England, and the Middle Atlantic States the mental worker is at his maximum in November instead of October, and April instead of May.

Chart 17 shows how human energy would be distributed over the earth if it depended on climate alone. It is remarkable how almost exactly it agrees with what we know to be the distribution of the great political power. Japan is meant to be included in the region of high power, but the scale of the chart is too small to make this plain.

From the time when man began to lose his tribal instinct and to assume national consciousness, in Egypt, the Mesopotamian Valley, and the region between the Caspian Sea and the Persian Gulf, he

has been founding empires of more or less enduring nature, and with few exceptions has builded towards the west, in the face of the prevailing winds. The center of Empire has steadily migrated along the

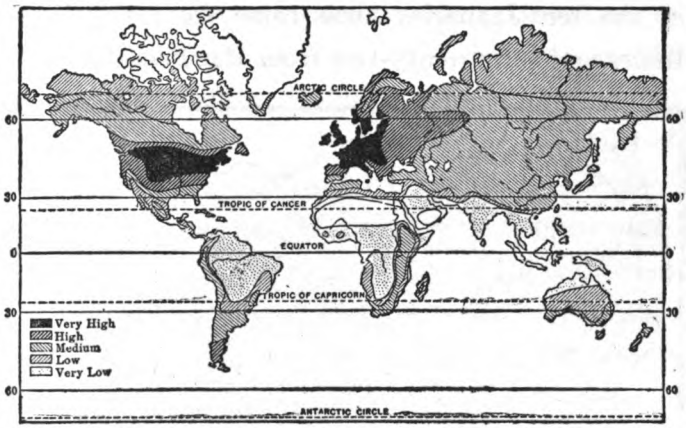


CHART 17. — MAP OF CLIMATIC ENERGY. (Huntington and Cushing.)

paths of greatest storm frequency. Examine Charts 10, 11, and 18 and note the relation between density of population and the closeness of the storm tracks. The figures at the center of each brace indicate the number of storms that originated in the region of the brace during a ten-year period, and the lines leading from the brace show the tracks followed by the centers of the storms. Bear in mind that each storm covered an area of from five hundred to one thousand miles in diameter, that it was a vast rotating eddy in the atmosphere, and that its center

of rotation followed one of these storm tracks. Twelve storms came from the West Indies during these ten Augusts, fifty-seven from the Rocky Mountains and none from the Pacific Ocean; while in the ten Januaries none came from the West Indies and but twenty-two from the Pacific Ocean.

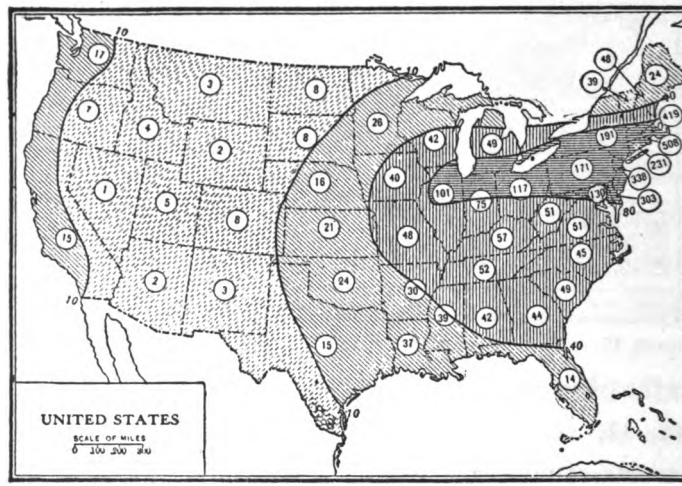


CHART 18. — DENSITY OF POPULATION IN THE UNITED STATES, 1910.

But the point to which your attention is directed is that, no matter what the origin, the tendency of each storm was to move towards the Ohio Valley, Pennsylvania, New York, New Jersey, and New England. This tendency gives to these regions the most frequent changes in weather, with alternations of sunshine and clouds, and changes in tem-

perature and air pressure — conditions essential to the development of the greatest human potential. Here population is the densest, civilization the highest, and the products of man's brain and hand greater and more diversified than elsewhere in this country, and probably than elsewhere in the world. The United States is abundantly blessed, for nearly its entire area is under the influence of high atmospheric potential. Only the region adjacent to the Gulf of Mexico and the southwest is outside of the favored area, and here the conditions are charted as medium, and not poor; at least not poor in comparison with many more purely tropical regions.

To-day the Empire of Human Greatness is centered over the United States, that is to say, greatness as expressed in material wealth, population, and homogeneously knit political institutions. Will it continue its westward migration, or will it remain here indefinitely for the working out of a civilization higher than yet has come to any of the nations of the past, or to other of those of the present? So far as atmospheric activities have to do with its translation from place to place, we may derive comfort from the fact that storm tracks do not cross the Pacific Ocean as freely as they do the Atlantic. In fact our

Rocky Mountains are a barrier to the passage of summer storms (Chart 10) and a reference to Chart 11 will show that of ninety-five winter storms that crossed our continent during the ten Januaries of which the chart is a record only twenty-two came into our area from the Pacific; and we know that these twenty-two largely originated off our coast somewhere between Hawaii and the Aleutian Islands. Let us hope that the center of earthly power has reached the end of its westward journey and that here it shall remain, always to exercise a just and beneficent influence upon the less favored portions of the earth.

Enough has been said to indicate that climate is nearly as important to animal life as it is to the vegetable existence, and that a cold climate, if it be not so extreme as to limit the production of cereal crops, and has frequent changes in temperature, pressure, sunshine, and cloud, favors the development of hardy and resourceful races of men; in fact, that no dominating race can exist without such stimulating conditions of climate.

CHAPTER XIII

HAS OUR CLIMATE CHANGED?

POPULAR OPINION ERRONEOUS, AS THERE IS NO CHANGE WITHIN THE PERIOD OF AN INDIVIDUAL LIFE, BUT MOMENTOUS CHANGES HAVE OCCURRED SINCE THE BEGINNING OF THE CHRISTIAN ERA

One of the hallucinations entertained by nearly every adult person is that the climate has changed since he was young. No matter what the scientists may say, he knows that it has changed. Fifty years ago did he not trudge to school for months every winter in snow knee-deep? Have not the old swimming holes in the brook dried up? Yes, he is a positive witness to an affirmative answer. Even the river of his boyhood, whose broad expanse he conquered in a swimming contest at the tender age of ten — as he views it after an absence of a quarter-century — has dwindled to little more than a creek, across which one easily may hurl a stone. Talk to him about no change in climate. He's been right on the spot, and knows. For all this, there

has been no change during the lifetime of this man; nor has there ever been during the life period of any individual. Mutations, to be sure, are going on all the time, but they are so minute that they do not accumulate a measurable quantity except in periods of hundreds or thousands of years. It is not the climate that has changed; it is the man. The natural action of the stream may have filled the swimming holes; or the stream may have entirely disappeared through much of the contiguous area being brought under cultivation and the water that formerly supplied its flow being utilized in the production of cultivated crops, which actually make use of as much if not more rainfall than the forest that formerly lined its sinuous banks and covered the near-by lowland. And then, snow knee-deep to a boy of ten hardly comes up to the ankles of a man of six feet two. Again, no one can remember the climate of his boyhood; he cannot carry the average in his mind; all that he can remember are a few instances of unusual conditions which because of their unusual character left an impress upon his mind. The river is just as wide as it ever was during the period of his lifetime, or that of his father, or of his grandfather; but he has lived on the broad Mississippi for many years, and when he goes back

to the scenes of his youth, his concept of what constitutes a river has undergone a revolutionary change since he left the parental roof to go forth and conquer the world.

An examination of the personal papers of Thomas Jefferson, in the State Department at Washington, by an official of the Weather Bureau, revealed a number of most interesting incidents in connection with the weather observations made by the author of the Declaration of American Independence. He says:

"A change in climate is taking place very sensibly. Both heats and colds are becoming much more moderate within the memory of even the middle-aged. Snows are less frequent and less deep. They do not often lie below the mountains more than one, two, or three days, and very rarely a week. The snows are remembered to have been more frequent, deep, and of long continuance. The elderly inform me that the earth used to be covered with snow about three months in every year."

But Jefferson and his neighbors were mistaken. Never during the period of authentic history has the snow covered the ground in Virginia an average of three months per year, or three months for a single year. These old inhabitants were like those of to-day, who remember only the abnormalities

of climate of twenty-five or fifty years ago, and in comparing the unusual conditions of long ago with the average of the present time they are deceived. I have known intelligent and well-meaning persons to declare that they knew from personal recollection that the climate of their particular places of residence had changed since they were young; that they had stable landmarks to show that the streams were drying up, the rainfall growing less, and the winters becoming milder, notwithstanding the fact that carefully taken observations of temperature and rainfall for each day for over one hundred years right at their places of abode showed no change in climate. We have a continuous daily record for one hundred years at New Bedford, Massachusetts, nearly as long records at several other places, and numerous records for over half a century. From these we learn that there has been no definite change in climate in this country during the past hundred years. There have been variations, such as an excess or a deficiency of rainfall over a considerable area, that have persisted for several years at a time; but in each case the conditions would ultimately come back to normal, or more often to an extreme of the opposite tendency to what had obtained immediately before. In sections where

the rainfall in bountiful years is barely sufficient for good crops, the people in the past have been prone to consider that the amount that they receive during the periods of excess is that which normally is due them, and thus to be unprepared for the dry periods that statistics tell us must certainly come. The matter of change of climate is most important to our sub-arid West, — to the western parts of Texas, Oklahoma, Kansas, Nebraska, and the Dakotas. Some years ago, when the tide of emigration was strong into these regions, there were several years of more than the average rainfall. The coming of population and the coming of extra rainfall were accidentally coincident, but that fact was probably responsible for the popular belief that civilization brings an increase in precipitation; that the breaking of the virgin soil, making it more permeable to the absorption of moisture; the planting of trees and the growth of crops, restricting the run-off; the roots of the new vegetable life drawing up the moisture from below the surface of the ground and transpiring it to the air through the leaves of plants; the enormous quantities of water vapor ejected into the air by the combustion necessarily incident to a considerable population, — all had combined to increase the rainfall and render the

sub-arid plains more responsive to the efforts of the husbandman. No one can fail to regret that this theory is not founded upon fact. But a moment's thought by the scientist will indicate to him that the volume of air is so great, and under the heat of the growing period its capacity for moisture so enormous, that the addition of vapor of water by the processes herein described, great though it be, is ineffectual to appreciably change the amount of the rainfall that nature beforehand had ordained should be precipitated.

The size of continental areas, the height and the trend of mountain ranges, the proximity of large bodies of water, and the direction of the prevailing winds are the factors that determine the amount of the precipitation of a region. Against these the puny efforts of man, stupendous though we think them to be, are entirely unavailing. As an illustration: If the Rocky Mountains were as old as the Appalachian Chain, and if they were eroded down to the height of the latter system, the winds from the Pacific Ocean, when they are drawn inland by the cyclonic storms of the Rocky Mountain plateau, or of the Mississippi Valley, instead of depositing their moisture on the west slopes of the first range of mountains, would carry the water vapor of the

Pacific clear to that place in the Mississippi Valley where it would meet the moisture drawn by the same storms from the Gulf of Mexico and the Atlantic Ocean. This will appear clear when one understands that cyclonic storms, such as are continually passing across our continent in periods of about three days each, may embrace in their eddy-like circulating systems areas one to three thousand miles in diameter, in which the winds from all directions spirally flow towards the center of the cyclonic system and the system itself is moving eastward.

The water vapor exists as a separate atmosphere from oxygen and nitrogen. It is screened off from the interior of continents by mountain ranges because it is condensed and precipitated as rain or snow at only moderate elevations. The windward side of mountains may, therefore, receive torrential rains while their leeward sides are entirely without precipitation.

It follows that if the Rocky Mountains were lowered as described, the entire United States would be green with rich vegetation and there would be no deserts anywhere within its broad boundaries. Also, if the Appalachian Range were as high as the Rocky Mountains — as it may have been at one

time — and if it extended around the Gulf of Mexico as well as up through our Atlantic Coast States, the vaporous atmosphere of the Atlantic Ocean and of the Gulf of Mexico would be prevented from entering the interior of the continent, and the power that to-day stands as the greatest bulwark of civilization would not exist. There would be but a narrow fringe of vegetation upon its east and its west coasts; the interior, with its vast cotton and cereal plains, would be a barren waste.

But to revert for a moment to Jefferson. He took his thermometer to Philadelphia when he proceeded there on a mission that would have caused any less serene and courageous spirit to forget all the small details of life. When the debates upon which hung the fate of a nation and, in fact, the lives of those that participated, were in progress, he coolly hung his thermometer on the wall and noted down its readings. Those historians who have described the intense heat in Independence Hall on the Fourth of July, 1776, were mistaken, as will be shown by reference to his observations, the early and the late ones of which doubtless were made at his lodgings. They are as follows: 6 A.M., 68°; 9 A.M., 72¼°; 1 P.M., 76°; and 9 P.M., 73½°.

Jefferson had one of the only two barometers in

this country at that time. James Madison (the Bishop, not the President) had the other. They took readings at the same hour of the day for a considerable period of time, and Jefferson discovered that changes in the pressure of the air always began on his instrument a few hours before they did on his friend's instrument a couple of hundred miles to the east of him. He came near discovering the fact that no matter what the direction of the wind, storms almost universally move from the west toward the east. When the British captured Washington they also raided Monticello, Jefferson's home in Virginia, and they destroyed his barometer. It has been said that he was as much distressed over the loss of his special instrument of science as he was over the burning of the National Capitol.

In "Descriptive Meteorology" (Appleton), the writer expressed doubt that there had been important changes in climate within the period of authentic history, but recent researches cause him to change his opinion, for the evidence now seems almost conclusive that marked changes have occurred. The powerful kingdoms of Sumeria, Babylonia, Assyria, and Persia, each ruling many centuries and dominating all or a large part of the vast region from the Persian Gulf to the Caspian Sea and westward to

the Mediterranean and Egypt, covering in their various reigns some four thousand years before Christ, could hardly have built their many great cities, supported their numerous millions of population, and developed the trade and commerce that was theirs with the climatic conditions as they exist to-day. As late as the opening of the Christian Era, Palmyra, in Syria, had a population of from one hundred and fifty thousand to two hundred thousand people, was opulent and adorned with a comparatively high civilization. To-day we see the wreckage of its vast aqueduct and irrigating systems, which are unable to gather enough water to wet their well-constructed walls, and a few hundred people eke out a miserable existence where once was a metropolis teeming with life under luxurious conditions. The same picture is shown in more or less relief throughout the greater part of the region that once maintained the greatest empires of antiquity. But we must not assume that such dry and nearly barren conditions are to continue forever; rather are we to imagine that within a cycle of a few thousand years this region may have a rebirth of abundant vegetation and again throb with the pulsations of abounding life.

The record inscribed by the waters on the aban-

doned and the submerged shores of inland lakes and seas in the Rocky Mountains, and on the shores of the Caspian Sea and other waters, is easy to read. It shows several great oscillations of climate in the United States and the most civilized portions of the world since the birth of Christ. For some time before and for several centuries after the beginning of our era there was a wet period. The Caspian Sea stood some one hundred feet higher than now and an abandoned beach and a clearly marked shore line show that Lake Owens, in California, on the east side of the Sierras, existed at a level nearly two hundred feet higher than now. There was an abundance of water to irrigate the Holy Land, and although the center of dominating human power had long since passed in succession Babylon, Assyria, Persia, Greece, Macedon, and was working its way towards the Atlantic, the Mesopotamian Valley was abundantly fruitful.

Then, for six or seven hundred years, with short-period variations of from thirty to fifty years, the world inhabited by civilized man and large areas in the temperate zone not yet civilized, grew drier. The Caspian Sea fell to a lower level than it now maintains, for the ends of great walls, constructed to keep out barbarians, and other evidences of the

handiwork of man, are now many feet below the surface of the water. This is the driest time known to history. Ellsworth Huntington of Yale, acting under the auspices of the Carnegie Foundation at Washington, made an examination of many of the stumps of the big trees of California, ranging in age from one to four thousand years. The thickness of each ring of annual growth is a legible record of the wetness or the dryness of the year. One would hardly think of these towering giants of the floral kingdom as being both thermometers and rain gauges, accurately measuring and recording the dry-hot and the wet-cold periods for thousands of years, and now at the end of their majestic careers revealing the hidden secrets of past ages. Huntington and Cushing, in " Principles of Human Geography", say:

" The rings dating from the time of Christ are thick and indicate that at that time, when Palmyra had an abundant supply of water, when Owens Lake overflowed and there was high water in the Caspian Sea, the big trees also had plenty of water and grew rapidly. Six or seven hundred years later, when Palmyra was abandoned and when the Caspian Sea stood fifteen or twenty feet lower than at present, the trees formed only narrow rings, because the climate was dry. The way in which

the growth of the trees has varied is shown in Figure 30. The high part of the curve indicates abundant rainfall. The black shading at the bottom indicates periods of comparative aridity."

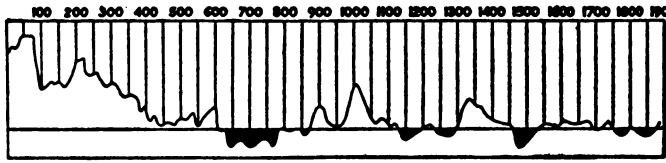


FIG. 30. — Changes in Climate in California during the Christian Era. Black shading indicates Drought.

Since the extensive system of observations by the Weather Bureau was inaugurated, some fifty years ago, it has been revealed to us that frequently the Ohio Valley would suffer a deficit in rainfall that would persist for periods as great as five or six years, while New England and the South Atlantic States, or other large areas of the country, had an excess. This is an illustration that excesses in one part of the country were balanced by shortages in other parts that occurred at the same time. But the long-period oscillations in climate that are measured in hundreds of years instead of tens — these changes seemed to have occurred simultaneously in the middle latitudes of Europe and America. These changes were simultaneous in an east and west direction. Now we have evidence of such long-period

changes in a north and south direction which were simultaneous, but of an *opposite character*, indicating that during the Christian Era the eastward track of storms has oscillated northward and southward. This would account for the occurrence of dry and of wet periods simultaneously throughout the vast stretch of territory between southern California and the Caspian Sea. In Guatemala, Yucatan, and other Central American countries there are ruins of cities and the evidence of an agriculture and a civilization that could not have been established with the torrential rains and jungle growths that now prevail in those regions. During the centuries when the big trees of California were receiving a large rainfall and making a thick annual growth, especially about the beginning of the Christian Era, because of a northward shifting of the climatic zone, the precipitation in Yucatan and Guatemala had so diminished as to leave only the amount of rainfall that could be economically employed in agriculture and in the rearing of great cities; and then, with a southward migration of the rain belt, these cities were suffocated with excessive precipitation, agriculture rendered impossible, and their temples and palaces buried beneath the gloom of a tropical growth.

If we are to reason from the records of the past

it seems highly probable that at least the middle latitudes of the Northern Hemisphere are slowly passing out of a dry period that has prevailed for the past two hundred years or more. For several hundred years all the great glaciers have receded, but we should not expect such recession to continue indefinitely. Geology furnishes abundant evidence that great changes took place in the climate of the earth during the prehistoric ages; that there were several glacial periods, the last occurring during pleistocene times, somewhere between twenty and fifty thousand years ago, and that there were intervals between the culminations of the Ice Ages of probably fifty thousand to one hundred thousand years. Between these long winters, that have meant death and desolation to much of what are now the most civilized portions of the earth, there have been warm periods of thousands of years' duration.

Fossil remains show that regions far north, now covered with perpetual ice, once supported a luxuriant flora and fauna, and many regions in the temperate and equatorial zones that are now deserts were once overgrown with forests and teeming with animal life. The fundamental thing of the cosmos is change — birth, growth, maturity; then decline, senility, death, decay, disintegration; and

always a renaissance, or new birth. Energy and life seem to be eternal, but ever undergoing change. The Great Ice Cap may again cover New England, the region of the Great Lakes, and flow southward to the Ohio River, but the change will be so gradual, if it does come, that there will be no great cities to be ground beneath the feet of the boreal monster; cold that will precede the ice cap will destroy them and they will be buried beneath the dust of accumulating ages before their icy tombstone is erected. Then the healthful and invigorating climate of the north part of our country will be transferred to the region of the Gulf of Mexico. Civilization will and must migrate with the shifting of the climatic belts. Because these changes cannot possibly concern us personally, we have almost neglected the study of the great forces that silently yet most persistently are at work altering the conditions under which future man must live and work out the destiny of coming generations.

Effects of Forests on Climate and Floods. Next to the fallacious belief in a change of climate during the life of an individual there are few if any errors that have gained such wide acceptance as a belief that the cutting away of the forests has caused a marked change in climate and especially in the frequency

and intensity of floods and droughts. The writer shared in the mistake with regard to the influence of the forests in restraining run-off and augmenting floods, until compelled by an order of the Congress of the United States to prepare a report on the floods of the nation that had occurred during the time of the gradual reduction of the forest areas. Dividing into two equal periods the forty years for which the Weather Bureau has comprehensive records of the rainfall upon the catchment basins of the Tennessee, the Cumberland, and the Ohio rivers, and for which it has records of the height of the rivers, contrary to his belief, he found that the high waters were no higher with a given rainfall, the floods of no longer duration, nor the low waters of summer lower, during the last half of the period than during the first half.

It is now pretty generally conceded by hydraulic engineers that the broken, permeable soil of the husbandman, frequently stirred by cultivation a part of the year and filled with countless billions of the tiny water-absorbing rootlets of the grasses and the cereal crops during the remainder of the annual period, is equally as good a conserver of the rainfall as the forests themselves, even if it is not better.

Some years ago the writer was delivering a series of Chautauqua lectures. He arrived at Devil's Lake, North Dakota, and found that the Chautauqua amphitheater was on the banks of Devil's Lake, once bordering the town, but now receded to a distance of five miles and confined to a narrow valley. In driving from the city to the lecture hall he remarked to his escort that they seemed to be traveling along the bottom of an ancient lake. His companion said, "Yes, a lake, but not an ancient one. Fifty years ago I used to dive off a springboard right there in front of the railroad station." In the course of his lecture the writer referred to this incident and told them that, contrary to their belief, their climate had not changed, that fifty years ago they sold their old lake to some gentlemen in Chicago and that they had been selling it over again every year since; that the former compact surface of the virgin prairie resisted the penetration of the rainfall, or at least only slowly absorbed it, and allowed it to collect in the depression adjacent to the city; but now, in the broken, permeable soil of the farmer it was taken up by millions of tiny rootlets and the hand of the Great Alchemist had transformed their lake into wheat, the sale of which was responsible for the presence of the speaker on the platform of a

largely-attended Chautauqua. The lake had gone never to return unless the region were again to become the haunt of the buffalo and the prairie dog instead of civilized man. The rainfall was the same, but it was now being utilized for the benefit of mankind.

In this problem of rainfall, floods, and the forests, most persons assume that when the forest is cut the land is at once denuded of vegetation. On the other hand a second growth will effectually shade the soil within a few months or a few weeks after the large trees are removed, and if the land is cleared and rendered fit for the plow, growing crops take the place of the forest-covering the greater portion of the time.

There is an abundance of reasons for the protection of our diminishing forests and for the creation of new forest areas without assigning to the forests functions that they do not exercise. The covering of an area by a great city, a village, a forest, a barn, or a tent modifies the climate of the particular area covered so long as the covering remains, but there is no appreciable climatic effect a few feet above the surface of the earth between a forest and a field of grain. The climate of a region like the American continent is controlled fundamentally by the great

oceans that wash its shores, by the trend of its mountain systems and their height, and by the direction of its prevailing winds. The vast vaporous atmosphere that flows inland from the Atlantic Ocean to the foothills of the Rocky Mountains, deluging our cereal plains with its life-giving precipitation will continue its pluvial generosity without any heed whatever to the puny scratchings of man upon the surface of Mother Earth. Nothing that man can do will intensify drought conditions on this continent or augment the volume of floods. It is time that we return to sanity in considering this matter instead of being frightened by the dire forebodings of well-meaning but purely visionary enthusiasts, no matter how noble their aspirations may be or how self-sacrificingly they have consecrated themselves to the redemption of humanity.

It is certain that forests restrict the flow of moderate falls of rain, but they do not restrain the flow of flood waters, because, surprising as it may seem to one who has not tested the matter, floods do not occur until after all surfaces, open fields and forests alike, have become saturated, and then the run-off of the two surfaces is equal.

CHAPTER XIV

CLIMATES FOR HEALTH AND PLEASURE

ONE'S LIFE WOULD BE PROLONGED IF, LIKE THE BIRDS, ONE COULD MIGRATE ANNUALLY WITH THE TEMPERATURE — CHRISTMAS IN MANY CLIMES — THE HOTTEST AND COLDEST PLACES IN THE WORLD

FROM what has gone before it is apparent that the regions of the earth where man is at his best estate, so far as climate can determine his environment, may be broadly defined in this country as southern New England, southern and central New York, the Middle Atlantic States, the Ohio Valley, the southern Lake Region and westward to the middle of Kansas and Nebraska; in Europe it includes the British Isles, France, Switzerland, extreme northern Italy, Austria, Germany, Belgium, Holland, and the extreme southern parts of Norway and Sweden. But in none of these regions is the climate equally good during all seasons. In fact there are two short seasons in each year when it is debilitating.

The great majority of the people, like galley

slaves chained to their oars, must remain in the same place throughout the year, others may have a vacation of several weeks, and still others are free to change their location as often as fancy calls them. The latter might well learn from the birds, and by migrating with the temperature, going far north in summer and far south in winter, maintain themselves throughout the entire year in the most perfect atmospheric conditions for health, happiness, and long life. Many a man of fifty, having accumulated enough to modestly supply his wants, could add ten to thirty years to his life, or might even double the period of his existence, by ceasing to strive after riches, and by giving himself up to a healthful movement about this beautiful world. His principal companions should be good books, — the study of which will enlarge his mental horizon and increase his capacity to see, comprehend, and enjoy, and fit him to speak, act, and think in ways that will inure to the public good. If he has not had the benefits of a college education, now is the golden opportunity to read, and have pleasure in the reading, popular books on Geology, Botany, Biology, Astronomy, and Physics, and to become familiar with the history of his own country and of the world. It need not be a period of idleness but one of beau-

tiful growth and of appreciation of the wonders of creation. And thus will his spirit be lifted up and fitted for a higher realm of existence in the world to come.

To those who must remain at home during heat spells, the advice is given to close not only the shutters but the windows on the east side of the house during the forenoon and do the same on the west side in the afternoon. The best night's sleep will be gained in a room facing north on any floor that is not next the roof; this room will be cooler if it is protected by another room on its east and one on its west side.

Long Life in the Open Air and the Sunshine. It is difficult to decide which most conduces to health and longevity: cheerfulness of mind and kindness of thought, or life in the open air and in the blessed sunshine. If one can enjoy both of these beneficent conditions they should live as long as they desire to remain on earth. *Most people live as long as they deserve to live.* It has facetiously been said that old age is a bad habit. The writer is disposed to agree with the humorist. Certain it is that few persons who believe in the limitation of life to three score and ten ever live beyond that period, while one should be possessed of a sound body and a supe-

rior mind at that age, with just anticipations of a third of a century of usefulness and happiness yet to come. As a man thinketh, so is he. We are just beginning to comprehend something of the wonderful power with which the Creator has invested us in the development and the care of our bodies. Anger, hatred, malice, jealousy, selfishness, fear, and worry create poisons that *may* bring on disease and death, but they *certainly* create a morbidity in the body that shortens life.

Sunshine destroys molds, bacteria, and other enemies of the human race that lurk in the darkness. It strikes dead the tubercle bacillus, which is such a scourge to mankind. Its remedial power comes largely from invisible light — the ultra-violet and the supra-red rays. You are blind to these rays but your skin and blood are not; they need the sunshine to give them vitality — not quack medicines or medical tonics for which, through the venal partnership of the Press, millions of the afflicted are induced not only to part with the money so much needed by their families and themselves, but to aggravate their sufferings. The sunshine of a high region is beneficial to those ill with coughs, colds, bronchitis, tuberculosis, anæmia, or other wasting diseases, because the upper altitudes are rich in many rays

that are beneficial, some of which are absorbed by the higher air and do not penetrate to the earth, or only reach the earth in minute quantities. There on the mountain the sun's rays are unpolluted by the dust and the bacteria of lower levels and the cities. But one does not need extreme altitudes. Two to three thousand feet may be sufficient.

Mountain and Sea Air and the Injury from Overbathing. The seashore is properly a great national playground during the heat of summer. Evaporated spray leaves a trace of salt in the air which, with the salt of the ocean, seems to be beneficial to many. Likewise there is no condition of life that is not benefited by the pure air of the wooded mountains. Those of moderate vigor may build up and maintain high vitality by continuous bathing in the cool, pure waters of mountain lakes and streams, but to many daily swimming in either fresh or salt water, except that it be for a mere dip and right out again, that is so cold as to be painful to the delicate sensations of the skin, is extremely debilitating to all bodily functions. Be moderate.

How to Find the Climate You Seek. At sea level in the tropics heat and moisture combine to produce great physical discomfort. But even under the equator it is possible to escape the tropical heat of

low levels by ascending four to six thousand feet, as can be done in some places in Porto Rico and Cuba. Most of the capitals of South American countries are located at altitudes of five to ten thousand feet; and Brazil is planning to abandon her capital at sea level and move the administrative machinery of government from the splendid city of Rio de Janeiro to a mountain location in the interior.

Any region of the Alleghany system of mountains above a thousand feet elevation possesses climatic conditions of therapeutic value. Illustration of this fact is seen in the success of the noted sanitaria in the Adirondacks, and in the mountain regions of North Carolina and Virginia, and in the northern part of New England. These sections are especially frequented by persons suffering from pulmonary diseases, or from nervous exhaustion, many of whom find not only relief but cure. Cool and healthful conditions of temperature may be found during the summer along the ridges and on the peaks of the entire mountain system that extends from North Carolina northward through Virginia, Pennsylvania, New York, and New England. The advice of one's physician should be sought, if one is ailing, before determining between the seashore and the mountains, but in general those suffering from diseases of the

respiratory organs are better located in the high levels, remote from the humid air of the ocean.

In winter Bermuda, Florida, Porto Rico, Cuba, the southern part of the Gulf States, much of Southern California, and Hawaii have balmy climates that permit of outdoor life without temperatures too high to be comfortable. Hawaii and Bermuda have mild climates not only during winter but throughout the entire year. The Riviera on the Gulf of Genoa and the beautiful Lake region of Italy enjoy the balmy air of the Mediterranean and are protected from the cold winter winds by the Alps.

From October to May that portion of the Rocky Mountain plateau that includes Arizona, New Mexico, and the northern interior of Old Mexico has one of the finest climates in the world for those afflicted with pulmonary diseases, as the sunshine is abundant and the day and night temperatures such as to permit an almost continuous out-of-doors existence. But the heat and the extreme dryness of the air in June, July, August, and the first half of September is irritating to the nerves and debilitating in general. Fortunately, when the conditions are not favorable in the extreme southwest part of the country, they are at their best in the

mountains of the Middle Atlantic States and New England, which offer to the pleasure or the health seeker a cool, pure air unsurpassed by any other region of the earth.

For an all-the-year climate for the health seeker, it only can be said that the ideal conditions do not continue at any place throughout the entire year. Possibly it is well that it is so, as a change may be beneficial for no reason except that it is a change. There is one great caution ever to be borne in mind, and that is that the health seeker must not continue or repeat the same unhygienic life in his new climate that brought on the disease in the old.

Climate of Cuba. The climate of one tropical country may differ materially from that of another in the same latitude as a result of difference in altitude, proximity to large bodies of water, and position with respect to the prevailing winds. Cuba being in the region of the northeast trade winds, more rain falls on the north side of its mountains than on the south side. The temperature of the southeast coast is higher than it is on the northern and western coasts, and the range of temperature everywhere between night and day is small, rarely ten degrees and usually much less. It therefore has a warm, humid, and monotonous climate, except in

the high levels of its mountains. The winter tourist will find the conditions of the greater part of the island somewhat similar to those in the region of Miami, Florida, but warmer. Havana is not so hot as Santiago. The highest temperature ever recorded at Havana is 101° and the lowest 50°. A fairly pleasant temperature always can be found within a short ride to the mountains. As in most tropical countries, Cuba has a dry and a wet season. The rainy season is May to October. In the early part of September, 1900, over thirty-six inches of rain fell within thirty-six hours at Santiago. As a rule the precipitation is in the shape of heavy showers, the clouds clearing as soon as the rain ceases; the showers usually occur in the afternoon. Cuba, in common with all the islands of the West Indies, occasionally is visited by destructive hurricanes; these storms mainly are confined to the period August to October. Frequent terrific thunderstorms occur in summer.

Climate of Porto Rico. Its mountainous character gives it a marked diversity of climate, torrential rains falling on the windward side of its mountains, while the leeward sides are comparatively dry. The highest temperature in San Juan since 1876 is 101° and the lowest 57°. In this city a cool breeze, known as the "briza", adds to the comfort of the late

afternoon and evening. The wet season begins a month earlier than in Cuba and lasts a month longer. San Juan is probably the most healthful city in the West Indies, but those reared in northern climates invariably suffer from its enervating influence after several years of continuous residence. Water is abundant, there being some seventy rivers and over a thousand small streams. The mountains are clothed in vegetation to their tops, and frost of a killing nature is practically unknown in the island.

Climate of the Hawaiian Islands. Much has been written about the charm of the Hawaiian Islands, their mountains, volcanoes, tropical verdure, and delightful climate. It is indeed a garden spot, and its soil and climate make it so. Nowhere in the islands does the temperature reach 90° at any time of the year, while at Honolulu, the largest city and the capital, a temperature lower than 60° is rarely experienced. Of course, as one ascends the high mountains for which the group is noted, much lower temperatures are encountered, while snow is not infrequent near the tops. July and August are the warmest months and January the coldest. The climate is soothing and dreamy and doubtless would prolong the life of many who are aged and

slowly passing to their end, and that of others of low vitality but no organic disease. Most of the rain falls November to May, but some falls in every month of the year. At Honolulu the amount is about that which falls in Wisconsin, but at a station in the Kohala Mountains one hundred and fifty-four inches have been measured as the rainfall for seven months, and forty-two inches for one month, the latter being a larger amount than the annual rainfall for the State of Iowa.

Climate of the Philippines. The highest temperature so far recorded at Manila is 100° and the lowest 60°. It is therefore warmer than either Havana or Porto Rico. The hottest months are April, May, and June, but the cool months are but a trifle cooler than the warm months, the annual range of temperature being but three degrees. The humidity is high at all seasons, and therefore the heat is oppressive and debilitating. The greater part of the rainfall of Manila is from June to October. Some relief may be gained from the low-level heat by retreat to the mountains of some of the islands. It will require several generations before the white man can become acclimated to this region. The islands lie between latitude 6° and 18° North. White children born of American parents and raised

there never will have the energy or ambition of their progenitors. If it were not for the invigorating air of the mountain resort at Baquio, many American officials could not continue a residence in the Philippines.

Climate of Bermuda in Comparison with the Popular Winter Resorts of Florida and California. It is a mistake to represent the climate of Bermuda as one of balmy sunshine during winter months. It has some glorious days, but a large proportion are cloudy, rainy, cool, and windy, and too cold for comfortable or healthful bathing from the middle of December to the first of May. And yet, its climate is healthful as a whole for nine months of the year and more stimulating than is that of Florida in winter. If one wishes sunshine and sea bathing in midwinter, it is better to go to Palm Beach, St. Petersburg, or Miami, Florida; but if one desires to have a moderately cool climate with a temperature of but little variation between midday and midnight, and occasionally a day with sufficient warmth and sunshine to justify a dip in the ocean or in the many land-locked bays with which the islands abound, one well may come to Bermuda. Such winter clothing as one naturally would wear in Philadelphia or Washington is what one will need in

order to be comfortable. Bermuda is no place for Palm Beach suits, outing shirts, and Panama hats in winter. Many tourists are mislead by the advertisements of steamship lines and bring clothing which is suitable only for early fall and late spring.

From the first of November to the middle of May the author occupied a room on the ground floor, facing the waters of Hamilton Harbor, and only fifty feet from the shore line. Here the diurnal range of temperature is much less than at Prospect Hill, where the Government's observations are made. From the middle of December to the middle of March, a thermometer in this room sluggishly ranged from 60° at night to 64° during the day, and days when the wind was high and rain falling — as occurs about one third of the time in winter — the thermometer would not vary a degree from 60° during the entire twenty-four hours. During April the range each day was from 68° at night to 70° at midday, and during November and May from 70° to 76°.

The selection of the best winter climate for health and for pleasure is so important that comparative data are here given of the most popular places that are easy of access to the people of the United States.

Bermuda has a wind velocity much greater than

that of any of the resorts named in the tables, and its relative humidity is about that of Florida.

The charm of Bermuda is that the flowers bloom, vegetables grow, and the trees remain green the year round. Even though frequent short showers may fall each twenty-four hours more than half of the days during winter, the soil is so porous that there is little or no mud, and life is largely one of the open air, with a winter temperature that conduces to activity; in fact, the temperature is such that one requires heavy clothing all the time if one is to sit inactive in the open. There is neither frost, fog, nor malaria, nor snakes.

Bermuda lies 666 miles south of New York City and about 700 miles due east from Charleston, S. C., and 293 miles from the southern edge of the Gulf Stream, which, if the truth must be told, exercises no such influence on the climate of Bermuda as highly colored advertising circulars would have one believe. It is the great ocean, upon whose surface the islands make the most infinitesimal dot, that controls the climate of the Bermudas. The Gulf Stream, wonderful phenomenon that it is, is a sort of bug-a-boo to some who never have intelligently studied ocean meteorology. Travelers tell of the superheated atmosphere they encountered on crossing the

Stream, and educators who should know better teach that the entire climate of Europe is markedly influenced by it. The fact is that there is no distortion whatever of the isothermal lines as they enter and leave the Gulf stream in any region north of Bermuda. (See Chart 14.) The climate of Bermuda and of Europe is controlled largely by the great Atlantic Ocean, not by this small river of warm water, which broadens out and loses its identity long before the coast of Europe is reached, and whose influence is soon dissipated in the vast expanse of ocean air. The ocean has a great circulating system, northward on the western and southward on its eastern side. This circulation pushes the isothermal lines northward on one side and southward on the other.

The islands of Bermuda rise some 15,000 feet from the floor of the ocean, and project above the water to heights varying from 50 to 260 feet above sea level. Like jewels nestling upon the bosom of a sub-tropical ocean these islands, from one half to three miles wide, are strung along so close that one almost can hop over from one to the other. They lie in the form of a fish-hook; from the hole where the line of the fisherman would be tied to the point of the hook is about twenty-six miles. The topography is irregular and picturesque. On land there

are caves and grottoes and subterranean lakes. January to May rose borders are abloom. In April the oleander is showing pink and crimson along every roadside, and the hedges hold these beautiful flowers for months; at Easter time lilies carpet the ground and perfume the air. Here morning glories have many forms and colors, which, with pendent bells, climb wide-spreading cedar trees, and wild passion flowers cover rocky cliffs.

The sea is so transparent that many feet below the surface the eye may follow the movements of marine life housed about by coral formations of strange devices. The colors of the sea are as changeable as the opal. Over shallow bottoms the colors are delicate shades of light green, over the shoals brownish hues, and beyond the dangerous reefs, which have sent many a sailor to his long home, and behind which numerous pirates of old have taken refuge, the waters vary from the light blue of the sapphire to deep green. The prismatic colors are forever laughing and dancing to the eye of the beholder. The shadow of a cloud, a ripple of the surface, a different angle to the fall of sunshine as the day advances, deepen or brighten the tints through a wide range of color.

Through the glass bottom of a boat one may look into the gardens. Rising from the bottom and

waving gracefully with the movements of the waters, like tree ferns moved by gentle zephyrs, are purple sea fans and tall black rods. Beautifully colored fishes dart about, or lazily bask in the sun that illumines their coral grottoes; weeds of many colors; green and scarlet sponges; vegetable growths delicate in formation and brilliant anemones cling to ledges of rock that here and there are tinted with pink.

Rival champions of the east and the west coasts of Florida may fortify themselves by a study of the tables. It may be noted that Miami and Tampa have the same midday temperature, but that Tampa has a greater range, the night temperature on the average falling five degrees lower than Miami; also that Tampa, which can be taken as typical of St. Petersburg, has but twenty-one rainy days on an average from December to March inclusive, while Miami has thirty-four. Bermuda has sixty-five days with rain during the period, with much wind. From these data one may select the climate that best suits him and he may know that the data are accurate and put forth by some one not interested in advancing the interest of one place over another. No country in the world has more delightful and healthful climates for winter and for summer than can be found in the wide domain of the United States.

U. S. WEATHER BUREAU

AVERAGE TEMPERATURE, HUMIDITY, DAYS WITH RAIN, CLOUDINESS, AND WIND AT

Los Angeles, California

DATA	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL
Maximum	64	66	67	70	72	77	82	82	81	76	72	67	73
Highest maximum	87	88	99	100	103	105	109	106	108	102	96	89	109
Minimum	44	45	47	49	52	56	59	60	58	53	48	46	52
Lowest minimum	28	28	31	36	40	46	49	49	44	40	34	30	28
Daily range	21	21	20	21	22	23	25	24	25	24	24	20	22
Relative humidity	65	69	69	72	76	76	75	74	73	69	62	58	70
Days with .01 or more rain	7	6	7	4	2	1	0	0	1	3	3	6	40
Percentage sunshine	65	68	65	68	63	69	76	79	77	76	77	74	71
Hourly wind velocity	5.1	5.3	5.3	5.2	5.2	5.0	4.7	4.6	4.5	4.5	4.6	5.0	4.9
Miami, Florida													
Maximum	69	70	76	80	86	89	89	89	88	82	76	70	80
Highest maximum	85	88	92	93	94	94	96	96	94	93	88	91	96
Minimum	58	59	64	66	70	73	75	75	74	71	67	61	68
Lowest minimum	29	29	39	46	62	61	69	67	62	53	38	32	29
Daily range	11	11	12	14	16	16	14	14	14	11	9	9	12
Relative humidity	81	80	79	76	79	82	82	83	83	80	79	81	80
Days with .01 or more rain	10	8	7	7	10	14	14	15	17	15	9	9	135
Percentage sunshine	60	62	67	73	67	60	64	64	62	53	61	57	62
Hourly wind velocity	11	11	11	11	10	9	8	8	9	12	11	10	10

U. S. WEATHER BUREAU (*Continued*)

AVERAGE TEMPERATURE, HUMIDITY, DAYS WITH RAIN, CLOUDINESS, AND WIND AT

Jacksonville, Florida

DATA	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL
Maximum	56	57	63	67	75	80	82	82	78	70	62	56	69
Highest maximum	81	86	91	92	108	101	104	101	99	95	86	82	104
Minimum	47	49	54	59	63	72	74	74	71	63	54	47	61
Lowest minimum	15	10	26	34	46	54	66	64	49	37	26	14	10
Daily range	9	8	9	8	12	8	8	8	7	7	8	9	8
Relative humidity	81	79	77	74	75	79	80	83	84	82	81	81	80
Days with .01 or more rain	9	9	8	7	9	13	15	15	13	10	8	8	124
Percentage sunshine	55	57	68	73	71	65	63	63	59	56	63	53	62
Hourly wind velocity	8	8	9	9	8	8	7	7	7	8	7	7	8
San Diego, California													
Maximum	62.2	62.6	63.6	65.2	66.0	69.2	72.3	73.6	73.1	70.4	67.7	64.3	67.5
Highest maximum	83	89	99	96	98	94	93	93	110	96	93	84	110
Minimum	46.4	47.6	49.6	52.4	55.5	58.7	62.2	63.6	61.3	56.6	51.4	47.9	54.5
Lowest minimum	25	34	36	39	45	50	54	54	50	44	36	32	25
Daily range	15.8	15.0	13.9	13.2	10.5	10.5	10.1	10.2	11.9	13.6	16.4	16.3	13.1
Relative humidity	71	74	74	75	77	80	81	80	79	76	70	68	75
Days with .01 or more rain	7	7	7	4	3	1	0	1	1	3	4	6	44
Percentage sunshine	67	67	66	69	58	62	67	72	72	73	76	74	68
Wind velocity	5.1	5.8	6.2	6.4	6.4	6.1	5.9	5.7	5.7	5.3	5.0	5.0	5.7

U. S. WEATHER BUREAU (*Continued*)

AVERAGE TEMPERATURE, HUMIDITY, DAYS WITH RAIN, CLOUDINESS, AND WIND AT *Tampa, Florida*

DATA	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR
Maximum	69	70	77	80	86	89	89	89	88	82	76	70	80
Highest maximum . . .	82	86	92	90	94	95	96	96	96	93	87	83	96
Minimum	51	52	58	61	67	71	73	73	72	65	58	52	63
Lowest minimum . . .	23	22	32	38	53	64	65	66	54	43	32	19	19
Daily range	18	18	19	19	19	18	16	16	16	17	18	18	17
Relative humidity . . .	82	80	80	75	75	80	82	83	84	80	81	82	80
Days with .01 or more rain	4	6	6	3	4	9	11	12	7	4	4	5	75

Bermuda

Observations taken on the hill at Prospect, 250 feet elevation, and furnished through the courtesy of Sir Frederick Stupart, Director of Canadian weather service

Maximum	67	67	68	70	74	78	84	85	83	78	73	69	75
Highest maximum . . .	79	75	78	80	83	88	92	94	91	88	82	79	94
Minimum	58	57	57	58	63	68	73	74	72	69	63	60	64
Lowest minimum . . .	39	45	44	40	49	54	65	64	59	60	49	46	39
Daily range of temperature	10	10	11	11	11	11	11	11	11	11	10	10	11
Relative humidity . . .	82	81	81	81	84	85	84	83	83	82	81	81	82
Days with .01 rain or more	17	16	15	12	11	11	12	15	14	15	16	17	171
Hourly wind velocity . .	15	16	15	14	12	11	11	10	11	12	13	14	13
Greatest monthly rainfall.	9.71	10.40	10.05	13.31	9.09	10.98	11.24	21.33	16.80	17.73	11.36	10.58	
Average rainfall	4.90	4.79	5.05	4.90	4.39	5.18	3.76	5.98	5.24	7.01	4.32	4.98	61.40

The Scientific American thus speaks of the uses of climatic data:

"What are climatic statistics good for? To this query one is tempted to retort: What are they *not* good for? Let us set down a few typical cases in which such data are desired.

"A merchant plans to undertake the sale of rubber coats in foreign markets. Hence he wishes to know all about the distribution of rainfall, both geographically and as to season. Which are the rainy regions of the globe? When do the heaviest occur in each of these regions? Where do the prevailing temperatures indicate the need of heavy coats, and where light?

"An invalid contemplates visiting a certain health resort. What mean temperatures occur there at the season of the proposed visit? What ranges of temperature between day and night? How much does the temperature vary from day to day? How much sunshine may be expected? Is the atmosphere moist or dry? What of the winds? Such are some of the questions he is likely to ask.

"A horticulturist proposes to introduce a foreign plant in this country. Where will he find the most favorable climate for it? In order to settle this question he first tries to secure certain information about the climate of the plant's original habitat — the march of temperature through the season of growth, average dates of first and last frost, normal fluctuations of rainfall, humidity, sunshine, etc. If the desired information is obtained, the next

step is to ascertain where (if anywhere) similar climatic conditions prevail in the United States, and this is generally an easy task.

"An engineer is planning a sewer system. He needs data of excessive rainfall for the locality under consideration, so that he may estimate the maximum amount of storm-water the sewers will ever need to dispose of in a given time. Their capacity should not exceed this amount beyond a reasonable margin of safety: otherwise cost of construction would be unnecessarily great.

"This list of examples might be extended almost indefinitely. It will suffice, however, to show how wide a range of climatic information is required to meet all possible demands. The different branches of industry are concerned with different sets of climatic data. One set helps determine the best location for a railroad: another the kind of goods that will be shipped over it and the way in which they will need to be packed and cared for during shipment. The climatic conditions that must be considered in planning a military campaign are quite unlike those that engage the attention of a hydrological engineer in laying out a system of irrigation. Climatic statistics of interest to aviators are not identical with those that bear upon the problems of ecology or forestry or sanitation. In short, climate means different things to different people."

Christmas in Many Climes. A general idea of the diversification of climate may be gathered from a description of the weather of some particular day

of the year as it exists in many different parts of the world. One is too prone to assume that the weather one has on a given day prevails everywhere. For the moment one does not consider the effect of distance from the equator, proximity to large bodies of water, and elevation above sea level and above the surrounding region. When a holiday or any day of special interest occurs, while the weather cannot make the occasion a success, it can quite effectively destroy all pleasure in the event. When we approach the day of all days in the year when two fifths of the people of the world celebrate the natal day of Christ, interest in the weather increases. The little ones of our clime pray that a mantle of snow may cover the ground, so that dear old Santa Claus may come with his reindeer and sleigh. The boys and girls long for the snow-covered hillsides and the glassy ponds; and even our good old grandmother smiles in anticipation of such a Christmas Day as gladdened her heart when she was a wee tot.

It may be interesting to know under what kind of skies the people of other lands celebrate this international holiday. In the Northern Hemisphere places near the same latitude may have weather conditions greatly at variance the one from the other, because of conditions previously explained. It is

our winter now; not because the sun is farthest from us, for in five days the earth will reach the time of perihelion in its course around the sun, and be nearer to the central luminary than at any other time of the year, but because the inclination of the earth's axis causes us to receive the rays of the sun at a lower angle than during any other season and its intensity is reduced. The conditions are reversed to the people of the Southern Hemisphere; they now receive the most direct rays of the sun and have their summer, which is intensified by the nearness of the earth to the sun.

The event that gave origin to our Christmas holiday occurred nearly two thousand years ago in Bethlehem of Judea; and it may be a new idea to us to try to think of the weather that prevailed at that time and the character of the Christmas Day that land may have this year. We know that it was not cold and cloudy on that eventful night so long ago, for the shepherds were feeding their flocks upon the hillsides and the Wise Men of the East beheld a star and followed it. The star shone brightly from the time they left Herod until they reached the place where the Infant lay. We may therefore judge that this part of their journey was made under a clear sky and that the same conditions

prevailed at Bethlehem. Weather observations made at Jerusalem, a few miles from Bethlehem, during modern times, show that during December there are less than fourteen cloudy days on the average. The prevailing winds are from the Mediterranean Sea, only thirty miles to the west of Bethlehem, and therefore rarely does the temperature exceed 65° during the day or fall to freezing at night. While there is evidence that the climate is drier now throughout all of the Holy Land than at the birth of Christ, it is highly probable that when He was born the stars were shining brightly and the hills were green and beautiful and the weather smiling its benediction upon the Son of God.

We now will glance at the weather that experience teaches us will probably prevail in some of the principal cities of the world on Christmas Day, and thus have impressed upon us the fact that on any day of the year humanity lives under widely differing weather conditions throughout the world.

In our own country we know that Maine is the home of ice, snow, and chilling blasts, while in California and Florida orange blossoms perfume the temperate air.

In London Christmas is not always bright and

comfortable, for on the average twenty-one days in December are cloudy and the temperature ranges from a few degrees below freezing at night to about 50° during the day.

In Paris the weather is about the same as in London. It has the same percentage of cloudiness, and its daily range of temperature is from 32° to 45°, slightly colder than London. The influence of wind direction and the relation of water and land areas to the location of a city are well exemplified in the fact that Paris, farther south than London, has a lower winter temperature. In the United States the coldest winter winds are from the northwest and they also would be so in Western Europe were it not for the fact that they draw from the ocean, whose waters are much warmer in winter than the interior of the continent of Europe. The northeast winds are therefore the coldest that come to Paris and London. In the first case they draw from the cold interior, and in the second case the air in passing to London from the northeast must pass over the North Sea and the extreme temperature of the cold land is somewhat modified by even this comparatively small body of water with the result that the average daily maximum temperature of London for December is five degrees

warmer than its neighbor some two hundred miles farther south.

Berlin and Vienna have the same degree of cloudiness, but there the similarity ceases. Berlin, only about one hundred miles from the Baltic Sea on the northeast and about double this distance from the North Sea on the northwest has an average range of but eight degrees between day and night temperatures, while Vienna, deep-set in the interior of a great continent, has a daily range of thirty-seven degrees, the average temperature swinging from 13° to 50° each day during December.

Constantinople was named after the Roman Emperor who made it his capital and who first protected the early Christians from persecution, then became converted and, in the manner of his time, forced others to accept the doctrine at the point of the sword. Here Christianity was first recognized and adopted as a State religion, but since the middle of the fifteenth century Constantinople has been the home of the Sultan of Turkey and the principal city of those who worship Muhammid as the prophet of God instead of Christ. This ancient city, so interwoven in the history of Christianity, has a delightful climate at Christmas time, the daily range being from between a little above freezing

and 65° or 70°, with clouds obscuring the sky about one half the time.

Historical Rome has about as many clear days as cloudy ones and the days are pleasant and the nights simply cool.

At Cairo, in the land where Joseph was sold into bondage and where Pharaoh raised him to the highest position in the land next to his own, no more delightful place can the traveler find at Christmas time. Only one day in three is cloudy and the gentle winds are warm and balmy, with a daily range in temperature of 12°.

In Calcutta there is a great amount of sunshine, only one day in five being cloudy, with an average daily minimum temperature of 58° and a maximum of 80°.

Bombay is also sunshiny at this time of the year and excessively hot, with a range each day from 66° to 88°. Here, as at Calcutta, Brahmanism and Buddhism rule instead of Christianity.

China, that enormous empire that believes in the ethical philosophy of Confucius, whose inhabitants have lived for four thousand years with less strife and bloodshed than any other nation, has as great a variety of climate during December in the widely separated parts of its broad domain as has the United

States. On any day of the Christmas month some parts of this country are bound in icy chains, while other parts are sweltering in a torrid temperature.

That wonderful Island — Japan — whose people have made such amazing strides in catching up with the most advanced civilization of the Occident, and who never have accepted Christianity, has a most delightful climate during winter, with a large amount of sunshine and moderate temperatures.

The vast Christian nation so long ruled by the Tzar, and now in such deplorable chaos, has a varied climate during December. From temperate conditions in the southern portion of its European possessions it gradually grows colder as one goes northward until a region of great severity is reached. At Petrograd the average night temperature is 6° below zero. At Moscow it is colder, the average of its minimum temperature being 11° below. Two thirds of the time it is cloudy at these two cities.

Verkhoyansk, in the central portion of Siberia, is nearly the coldest place in the world where observations are regularly taken. There Christmas Day may be ushered in with a temperature as low as 75° below zero. For days at a time this extreme cold remains, the warmest part of the day varying but little from the coldest.

In many of the cities of the Southern Hemisphere Christmas Day is likely to be such as will cause the sojourner to long for some cooler region. There it is midsummer, the grass is green and the fruit is on the tree. We of the North could hardly realize that it is December. In the pampas of the Argentine Republic everything is parched. The white stucco walls and the red tile roofs in the cities reflect the intense rays of the sun into the shimmering air. In Rio de Janeiro the days are almost unbearable, the daily temperature rising to 100° and over at midday and seldom falling to 60° at night. Bear in mind that the greater part of the area of South America lies between the equator and 30° south latitude. But wherever in these South American cities one can escape to an elevation of several thousand feet a pleasant temperature may be found.

At Santiago, Chili, it is more comfortable than in Brazil, for the nights are cool, even though the day temperatures rival those of the Argentine Republic. But here the cool mountain tops are almost hanging over the coast cities.

At Cape Town, in the extreme south part of Africa, two days out of three are clear and the daily range of temperature is from 48° to 83°, making fairly pleasant conditions during the Christmas holidays.

At Melbourne, Australia, one half of the days are cloudy, and the temperature is moderate, having a range from 54° to 75°.

Thus we see that the climatological features of the world, not only on Christmas but on any other day of the year, are as varied as the hopes and wishes of man, and whatever his desires or physical necessities may be, a climate may be found under the influence of which he may find pleasure and gain health.

The Hottest and the Coldest Places in the World. It is an innate characteristic of the human race to be interested in the abnormal, whether it be in the achievements of men or in the extremes of natural phenomena. This is especially true with regard to the weather. During periods of extremes of heat or cold the natural inquiry is as to whether there ever has been a period of equal or greater severity. Although suffering intensely there always is a desire to "beat the record." It therefore may be of interest briefly to refer to the hottest and the coldest places in the world.

North America. One of the most torrid places in the United States is in that remarkable region known as Death Valley. It is located in Southern California. Its name is supposed to be derived from a

melancholy tragedy that occurred in 1850, in which every member of a party of emigrants perished in Death Valley from thirst and exhaustion, leaving the bones of themselves and their animals to whiten in the sun. The valley is the bed of an ancient salt sea which existed when the climate was much wetter than now; its soil is largely composed of sand, salt, and borax. The borax deposits are large; at places they form crusts that support the weight of travelers. The length of the valley is seventy-five miles, but it is narrow at the bottom, in places being no more than six miles. One of its remarkable features is that its bottom, in many places, is three hundred feet below the level of the sea, one hundred miles to the west. It is fed by several small streams and innumerable warm springs, the water from which is entirely absorbed by the porous soil, although water may be found by digging down a few feet. The water is unfit for use. It is a desolate and forbidden region, inhabited by gnats, toads, lizards, and snakes. However, the employees of a company engaged in the business of marketing borax spend a portion of each year there.

In 1891 an observer of the U. S. Weather Bureau remained in Death Valley from May to September, during which time he made daily observations of

the weather. His experience was a most trying one, drawing heavily upon his physical and mental stamina to complete the period of time that had been set for him. For the entire time of one hundred and fifty-four days less than one half an inch of rain fell. There occurred several days in succession with a temperature of 122°. However, this is not the highest temperature ever recorded in the United States. In July, 1887, at Mammoth Tank, in the Colorado Desert, the temperature reached 128° in the shade, and again, in 1884, 124° was reached at the same place. On July 18, 1891, in Death Valley, the maximum was 120° and the minimum 99°, making an average for all hours of 108.6°. The extremely high temperatures reached in the Colorado Desert, which embraces a portion of Southern California and Arizona, do not vary greatly from those of Death Valley; they are not exceeded anywhere in Central or North America. Such degrees of heat, if experienced for two or three weeks in the more humid regions of the eastern half of the United States, would nearly depopulate the region by the havoc of death.

The lowest temperatures in the United States occur in extreme northern portions of Minnesota, North Dakota, and Montana, where temperatures

from 50° to 55° below zero have been recorded. It is interesting to note that in this same region the summer temperatures have risen to readings of from 105° to 108°. Of course this heat is quite different in its effects upon life from the heat of the Gulf or Atlantic coasts. One feels a marked difference between the sun and the shade temperatures in these semi-arid regions. Sunstroke is infrequent and death seldom results from exposure, as it does in the East.

The region of severest cold in North America is found about the Great Bear Lake in the British Northwest Territory, where temperatures of 58° below zero have been recorded.

South America. The hottest portion of South America is in the interior, with extensive systems of mountain ranges along the coast preventing the inward flow of the moist rain-bearing winds from the ocean. In a stretch of country extending from Uruguay northward into the interior of Brazil, the average of the highest temperature of each year for a period of several years is 104°, with individual readings much higher. Except on the top of the mountains, or well up their sides, no severely cold weather occurs in South America, seven eighths of its territory lying between the equator and latitude 30° south.

Africa. In Africa is to be found the hottest region of the world, the great Desert of Sahara, upon whose sands beats down the fierce tropical sun with merciless intensity. Here shade temperatures of 130° are frequently experienced. Only those bred to extreme tropical desert heat can long live under such conditions. In a portion of the desert lying between Egypt and the Red Sea the temperature has been known not to fall below 113° for a period of ten days, while on several nights the lowest temperature reached was 118°, with a practically calm air. Africa lies with about one half of its immense area on each side of the equator, and the greater part of its territory inside the Tropical Zone. Except in a few isolated cases on high mountains, temperatures as low as zero never are experienced.

Europe. The warmest portion of Europe is in the region round and about the Mediterranean Sea. The coldest places in all Europe are in the western part of Russia and in the northern part of the Scandinavian Peninsula. Here the average of the coldest days of winter is 50° below zero.

Asia. It is difficult to determine in what part of Asia the highest temperature occurs, as data from many parts are meager. It is known however that extremely hot weather prevails in India and Arabia.

Siberia, however, experiences the coldest weather to be found anywhere in the world. At Werchojansk, in that country, a temperature of 90.4° below zero was observed in January, 1884, while the average temperature for the whole month was 69.4° below zero.

The coldest weather of the world is not found at the North or the South Pole, as many suppose, but rather at the center of vast continents, far from the modifying influence of oceans.

Australia. In extreme heat the interior of Australia is fairly comparable with northern Africa, Persia, Afghanistan, and northern India, where every year maximum temperatures of 115° occur, and where, at times, an extreme heat of 120° or 125° is experienced in the shade.

We now know that the forceful, dominating peoples come out of the regions where the heat is not so great as to debilitate, nor the cold so fierce as to deaden the mental and the physical faculties; but rather from the region of the thoroughfare of the great circum-polar storm tracks, where there are frequent changes of weather from sunshine to clouds, and where there is a fairly wide difference in temperature between night and day and between winter and summer. For the best coördination

of the mental and the physical faculties, so as to produce the most efficient composite of man, the temperature should range between 45° and 50° at night and between 65° and 70° during the day, with about sixty-five to seventy per cent. of relative humidity. Some day we will artificially create the exact conditions of temperature and moisture needed for patients in hospitals and sanitaria. Science is persistently seeking means to increase comfort and prolong life.

CHAPTER XV

CONDENSATION

HOW HAZE, RAIN, SNOW, HAIL, FROST, CLOUD, AND FOG ARE FORMED

Haze is what might be called diluted cloud or fog; it differs from them only in the degree of its density. One may see several miles through a haze, because the minute particles of spheres of water or ice are far apart in comparison to what they are in fog or cloud.

Raindrops vary in size from 0.03 to 0.20 of an inch in diameter. Each drop is composed of literally millions of minute specks of water that have condensed each about a minute mote of dust. These motes are a million of times below anything that may be seen with the most powerful microscope. Recall what is said in Chapter IV about the size of the molecules in water: if a raindrop were enlarged to the size of the earth, the molecules of which it is composed would be no larger than a baseball, and

the smallest of them no larger than tiny green peas. Without free surfaces upon which condensation may begin there can be no rainfall. Dust motes furnish these surfaces; without them air may be supersaturated without condensation occurring except where it comes in contact with solid matter. The little spherical masses of water join together so as to form raindrops in some manner not well understood. When enough of them coalesce so that the weight of the drop is too heavy to be supported by the motions of the air it falls to the ground, or is evaporated by the warmer and drier lower air. Raindrops form mainly in the stratum between one and three miles above the earth. It is seldom that the stratum of air next the earth is saturated, even during rainfall. One might evaporate millions of gallons of water and find no dust as a residue, or at least nothing visible to the human eye, so infinitesimal are the motes of condensation. As high as thirty millions have been shown to exist in a single cubic centimeter of air (Chapter IV), and a million times that number could occupy such space without being visible, and the dust mote is composed of molecules, and the molecules of atoms. It is impossible for the human mind to grasp the idea of the degree of smallness to which the atom attains,

and when one tries to conceive of the electrons from which the atom is built up, he must try to think of them not as objects but as the place or condition where matter slowly fades away into nothing; as the place possibly where matter is transmuted into electrical energy and ceases to exist.

The raindrop cannot be formed at great altitudes because the vaporous atmosphere is confined to low levels by temperature. At 100°, which often exists at the bottom of the atmosphere, air at saturation contains 19.77 grains the cubic foot; at 80°, 10.93; at zero, .04; and at −40°, which always may be found at about four and one half miles high, air cannot contain in excess of .01 of a grain. Raindrops are mainly caused by the cooling of air down to its dew point.

Rain Water Is Not Pure. Hailstones often incase foreign matter that has been carried upward by violent winds. Rain water is pure when it is condensed, but it gathers other matter as it falls, such as the pollen of plants, and the broken siliceous shells of microscopic life carried by winds of the tropics; it also washes ammonia from the air in small quantities, — about thirty pounds per acre in the eastern half of the United States each year. A raindrop increases in velocity as it falls until the re-

sistance of the air becomes just equal to the weight of the drop; after that it falls at a uniform rate. It will surprise many to learn that if it were not for the retardation effected by the resistance of the air, a raindrop falling from only half a mile would be as dangerous to life as a rifle bullet, for the speed with which a projectile travels can be made sufficient to compensate for its softness or yielding qualities.

How Much Water Is It Possible to Precipitate from the Earth's Atmosphere? If the entire amount of water vapor present in the atmosphere were precipitated instantly it would furnish a rainfall of only two inches for the whole surface of the earth. A steady downpour for twenty-four hours usually amounts to some two or three inches. Over small areas and in exceptional cases as many feet have been known to fall in that time, as fresh, vapor bearing winds steadily blew into a storm center, rose, discharged their burdens as they cooled with ascent, and then flowed away, again to be charged with moisture when they came into contact with wet surfaces. It is impossible to drown the entire earth with rainfall, no matter how long continued.

Snow. Snow is water vapor condensed in the congealed form, without passing through the liquid state. When the minute pieces of ice of which the

flake is composed are magnified several hundred times they are found to be composed of the most wonderfully beautiful figures. Thousands have been photographed, but the versatility of nature is so great that no two ever have been found that were exactly alike. Figure 31 gives some idea of their infinite variety and perfect symmetry. They are always governed by the number six. The most common form at the beginning of winter is a six-rayed star, each ray branching. As the winter advances and the cold becomes more severe, the flakes take a simpler form, finally becoming slender six-sided prisms with sharp ends, under the influence of severe cold waves. Great pain is inflicted on the exposed parts of the body when these prisms are encountered in a high wind.

When condensation takes place in a warm stratum it will be in the form of minute massive spherical particles or spherules. If these spherules are then whirled aloft by ascending currents it is possible for them to be cooled to far below the freezing point without turning to ice; they will, however, congeal instantly when they touch one another or are jostled by touching any solid or liquid surface. They may give a coating of ice to the limbs of trees and the coating may increase until the limbs break,

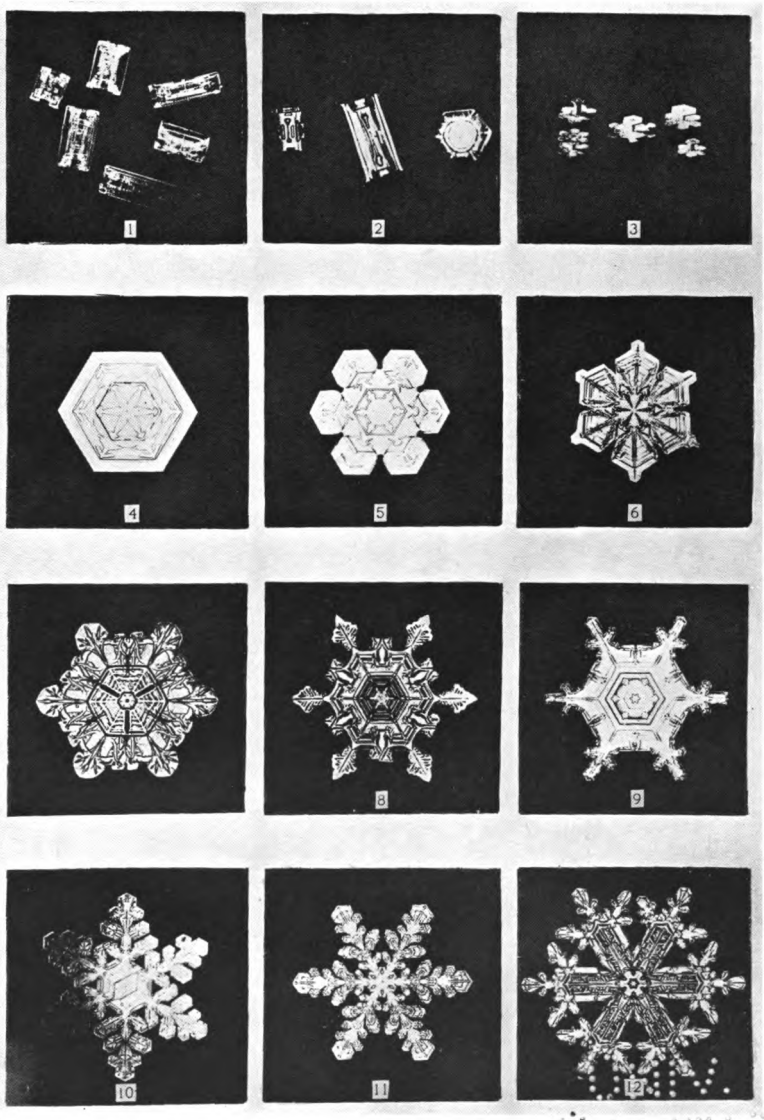


FIG. 31. — SNOW CRYSTALS.

and the surface of the earth thus may be covered with thin ice called *sleet.*

Hail. There is a difference of opinion among meteorologists as whether the thunderstorm whirls about a vertical axis, like the tornado and the hurricane, or whether it rotates about a horizontal axis. One may well account for the formation of the hailstone by assuming that its alternating layers of snow and ice are caused by the horizontal roll of a thunderstorm, the under part of which has a temperature at or above freezing and the upper half much below freezing. A raindrop is formed in the lower part, frozen in its course through the upper part, receives a fresh coating of water or snow with each revolution and a freezing before its circuit is completed. It thus gains in size until it becomes too heavy to be sustained by the whirling storm-cloud, when it falls to earth. Hail usually has the size of small peas, but occasionally it falls in chunks sufficiently large to kill cattle in the fields. On August 15, 1883, a hailstone weighing eighty pounds is said to have fallen in Kansas.

Frost. Frost is composed of beautiful crystallizations, similar to snow. Chapter VII describes the process of formation in detail.

Cloud. Cloud is formed by the cooling by ex-

pansion as currents of air are carried aloft. Clouds are composed of minute watery droplets or of ice spiculæ, depending on their temperature, and the latter largely is determined by elevation. A cloud differs from mist or rain in the size and number of its particles, and from fog in its position and the method of its formation. There are three fundamental formations, the cirrus, cumulus, and stratus. The others are combinations of these. The cirrus are thin, high, veil-like clouds, always composed of ice spiculæ; the cumulus look like great banks of snow with bulging, oval tops in which thunder heads may form; the stratus spread out like a great blanket. The cirrus usually fly at the top of the storm stratum, some five to seven miles high; the other clouds at some lower level. When rain is falling from a cloud, it is called nimbus.

Fog Is Cloud at a Low Level. It is formed by warm water vapor rising from lakes or rivers into the cool night air at the bottom of valleys, or by the cold waters of oceans being forced up over a bar, where the coldness that they impart to the adjacent air condenses some of its vapor.

Artificial Rain Making. Many swindlers have preyed upon the credulity of the public by claiming to have a process for the making of rain, and in some

cases large sums of money have been paid by commercial or other associations to these charlatans. In 1892 the United States Congress appropriated $20,000 for the testing of the theory that rain could be created by the setting off of large quantities of explosives. The experiment was unsuccessful, as the scientists of the Government insisted it would be. The Greeks had a popular belief that when a host of their soldiers went out to meet an army of Persians the vapor rising from the hot breath, blood, and sweat of the struggling mass was later condensed into rain by the concussion of the battle clubs and the hoarse cries of the victors, and many of the veterans of our Civil War were firm in the opinion that their great battles were followed by rains that were the result of the cannonading. Both the Greeks and our American soldiers were mistaken. Rain often has fallen at the close of great battles, not because of the concussion of the conflict, but because rain falls on an average of one day in three in the regions where most of the great battles have been fought, and the movement of armies began on the fair days when travel was good. If it were the custom to begin battles on rainy days we would have the contrary and equally erroneous theory that concussion clears the atmosphere.

Prevention of Hail by the Firing of Guns. Even a Papal decree was not entirely effective in preventing the people in southern Europe from ringing the church bells to prevent the formation of hail when a storm threatened, and within the past quarter-century large grants of public money were foolishly wasted in the firing by the vineyardists of France and other parts of Europe of a gun specially designed to destroy hail clouds. These guns sent harmless smoke rings a few feet aloft. The writer felt constrained to employ the extensive machinery of the Weather Bureau to counteract the effect of glowing accounts of the success of these guns that were sent to this country by some of the ignorant persons employed by this Government to represent us as consuls abroad. Even though the hail-destroying guns occasionally were choked with hail it was difficult for scientists to prevail upon the public to stop their foolish and wasteful practice.

CHAPTER XVI

DEVELOPMENT OF THE AMERICAN WEATHER SERVICE

THE LARGEST AND THE MOST EFFECTIVE METEOROLOGICAL BUREAU IN THE WORLD

EVEN to those who are familiar with the application of meteorological science to the making of weather forecasts, and with the material benefits accruing to the commerce and industry of the United States from timely warnings of marine storms, frosts, and cold waves, it will be interesting to note that at the time of the founding of the first of the thirteen original Colonies, at Jamestown, Virginia, in 1607, practically nothing was known of the properties of the air or of methods for measuring its forces. To-day electrically recording automatic meteorological instruments measure and transcribe for each moment of time at two hundred stations in the United States, the temperature, the air pressure, the velocity of the wind, the direction of the

wind, the beginning and ending of rainfall, with the amount of precipitation; and the presence of sunshine or cloud; and three thousand voluntary observers each day record the temperature and the rainfall.

That we live in an age of great intellectual acumen, and that he is indeed a wise prophet who can even dimly outline the possibilities of the next century, is fitly shown by the development of meteorological science during the recollection of the present generation; although one must admit that in the making of weather forecasts, valuable as they are, we have not advanced beyond the partly empirical stage. It is, therefore, improbable that in the making of these forecasts we shall ever attain the accuracy acquired by theoretical astronomy in predicting the date of an eclipse or the culmination of any celestial event.

It was not until 1644, twenty-four years after the landing of the Pilgrims at Plymouth Rock, that Torricelli discovered the principle of the barometer and rendered it possible to measure the weight of the superincumbent air at any spot where the wonderful yet simple little instrument might be placed. Torricelli's great teacher — Galileo — died without knowing why nature, under certain con-

ditions, abhors a vacuum, but he *had* already discovered the principle of the thermometer. The data from the readings of these two instruments form the base of all meteorological science. Their inventors as little appreciated the value of their discoveries as they dreamed of the coming great western empire which should first use their instruments to measure the inception and development of storms, and later, with the aid of the electro-magnetic telegraph, to give warnings to threatened regions of the approach of hurricanes, cold waves, floods, and frosts that have been worth at least one hundred million dollars to this country during the past ten years without counting the many thousands of lives saved among mariners.

Doctor John Lining, of Charleston, South Carolina, kept a daily record of the temperature in this country as early as 1738, although the accurate thermometers of Fahrenheit had then been in use but a few years and the errors due to imperfect mechanical construction may have been considerable as compared with the refined instruments now used for measuring temperature. About one hundred years after the invention of the barometer, viz., in 1747, Benjamin Franklin, the patriot and statesman, the diplomat, the scientist, divined

that certain storms may move in a direction opposite to the blowing of the wind and that they progress in an easterly direction. It was prophetic that this idea should come to him long before any one had ever seen charts showing observations simultaneously taken at many stations. But although his ideas in this respect were more momentous than his act of drawing the lightning from the clouds and identifying it with the electricity of the laboratory, yet his contemporaries thought little of his philosophy of storms, and it was soon forgotten. It will be interesting to learn how he reached his conclusion as to the cyclonic or eddy-like nature of storms. He had arranged with a co-worker at Boston to take observations of an eclipse at the same time that Franklin was taking readings at Philadelphia. Early on the evening of the eclipse an unusually severe northeast wind and rainstorm set in at Philadelphia and Franklin was unable to secure any observations. He reasoned that as the wind blew fiercely from the northeast the storm, of course, was coming from that direction, and Boston must have experienced its ravages before Philadelphia was reached. Reports indicated that the storm was widespread. What was the surprise of Franklin, when, after the slow passage of

the mail by coach, he heard from his friend in Boston that the night of the eclipse had been clear and favorable for observations, but that a terrific northeast wind and rainstorm began early the following morning. Franklin then sent out inquiries to surrounding stage stations and found that at all places southwest of Philadelphia the storm began earlier and that the greater the distance the earlier the beginning as compared with its advent in Philadelphia; but northeast of Philadelphia the time of the beginning of the storm was later than at the latter city, the storm not reaching Boston until twelve hours after it began at Philadelphia. In considering these facts a line of inductive reasoning brought him to the conclusion that the wind always blows towards the center of the storm; that the northeast storm which Boston and Philadelphia had experienced was caused by the suction exercised by an advancing storm eddy from the west which drew the air rapidly from Boston toward Philadelphia, while the source of the attraction — the center of the storm eddy — was yet a thousand miles to the southwest of the latter place; that the velocity of the northeast wind increased as the center of the storm eddy advanced nearer and nearer from the southwest until the wind reached

the conditions of a hurricane; that the wind between Boston and Philadelphia shifted its direction so as to come from the southwest after the center of the storm eddy had passed over this region; and that the force of the wind gradually decreased as the center of attraction — which always is the storm center — passed farther and farther away to the northeast.

Another man whose name is dear to the heart of every patriotic American conducted, in conjunction with a friend, a series of weather observations, beginning in 1771 and continued during the stirring times of the Revolution. This was the sage of Monticello, Thomas Jefferson.

During the first half of the nineteenth century, nearly a hundred years after Franklin's northeast rainstorm, Redfield, Espy, Loomis, Henry, and other American scientists laboriously gathered by mail the data of storms after their passage and demonstrated their principal motions to be such as Franklin had supposed. Professor Joseph Henry, Secretary of the Smithsonian Institution, in 1855, constructed the first daily weather map from simultaneous observations collected by telegraph. He did not publish his forecast but used his large wall map for the purpose of demonstrating the feasibility

of organizing a Government weather service. If there were no other achievements to the credit of the institution founded in this country through the benevolence of the English philanthropist, James Smithson, who, by the way, never gazed upon our fair land, the work of the Smithsonian Institution in connection with practical meteorology would always give it a warm place in the hearts of those who believe the crowning achievements of science consist in giving to the world knowledge which results in the saving of human life, the amelioration of the sufferings of human beings, and the acceleration of the wheels of commerce and industry.

Although American scientists were the pioneers in discovering the progressive character of storms and in demonstrating the practicability of weather services, the United States was the fourth Government to give legal autonomy to a weather service. Holland established a weather service, with telegraph reports and forecasts, in 1860; England followed with a smaller service in 1861; and France in 1863. But none of these countries has an area from which observations can be collected great enough to give such a synoptic picture of storms as is necessary in the making of forecasts of much utility. It would require an international service, embracing

all the countries of Europe, to equal, in extent of the area covered and of the accuracy of its forecasts, the service of the United States, which was begun in 1870, as the result of agitation by Lapham, Henry, Abbe, Maury, and others.

The vast region now brought under the dominion of twice-daily synchronous observations embraces an area extending two thousand miles north and south, three thousand miles east and west, and so fortunately located in the interest of the meteorologist as to include an important arc on the circumpolar thoroughfare of storms of the northern hemisphere. Simultaneous observations, collected twice daily by telegraph from two hundred stations, distributed throughout this great area, renders it possible at several central offices, where all the reports are received, to present to the trained eye of the forecaster a wonderful panoramic picture of atmospheric conditions. Each twelve hours the kaleidoscope changes and a new graphic picture of actual changes is shown. The movements of storm centers and cold-wave areas are noted and estimates made as to their probable course during the next twenty-four hours. Where else can the meteorologist find such an opportunity to study storms and atmospheric changes?

In 1870, and for ten years thereafter, our forecasts and storm warnings were looked upon by the press and the people more as experiments than as serious statements. The newspapers especially were prone to facetiously comment on the forecasts, and many were clamorous for the abolition of the service during the first years of its existence. There was some ground for the criticisms. We knew nearly as much about the mechanics of storms at that time as we do to-day, but we had not, by a daily watching of the inception, the development, and the progression of storms, trained a corps of expert forecasters, such as now form a part of the staff of the Chief of the Weather Bureau, and from which the writer was graduated before he became Chief. Along about 1880, mariners began to note that danger signals were, in far more than a majority of cases, followed by heavy winds; they began to reason that it would be better to take precaution against storms that never came, than to be unprepared for those which did come according to the forecasts.

It is a fact that many times, by the operation of forces not indicated by the surface readings, the barometer at the center of a storm begins to rise and the velocity of the whirling mass to decrease. In

such a case the storm signals placed in advance of the storm center would fail to give the proper information. Again, the storm center may suddenly acquire a force not anticipated, or it may pursue a track considerably divergent from the normal for the location and season. In this case, also, the forecasts may warn some cities that fail to receive the effects of the storm. However, during the past few years the staff of the Weather Bureau, which includes the ablest meteorologists in the United States, has made a study of the peculiarities of the different types of storms occurring in the different localities during the various seasons of the year, their line of travel and the force they may be expected to attain. Competitive examinations have been held to test the comparative merits of those who, by natural ability, are best fitted to correctly and quickly correlate in their minds the conditions shown on a meteorological chart, and to make accurate deductions thereform as to the development, movement, and force of storms. This line of work and investigation has resulted in improved forecasts; so much so that mariners now universally heed the storm warnings; horticulturists and truck gardeners make ample provision for protection against frost; the shippers of perish-

able produce give full credence to the cold wave predictions. Of the many West Indian hurricanes which have swept our Atlantic seaboard from Florida to Maine during the past many years, not one has reached a single seaport without danger warnings being sent well in advance of the storm; and few unnecessary warnings have been issued. The result is that few disasters of consequence have occurred. Large owners of marine property estimate that one of these severe storms traversing our Atlantic coast in the absence of danger signals would leave not less than three million dollars' worth of wreckage. Twice a census was taken just after the passage of severe hurricanes to determine the value of property held in port by the danger warning sent out in advance of the storms. In one case the figure was placed at thirty-four million dollars and in the other thirty-eight million dollars. Of course this does not represent the value of property saved. It simply shows the value of property placed in positions of safety as a result of the danger signals and warning messages sent to masters.

On January 1, 1898, an extensive cold wave swept from the Rocky Mountains eastward to the seaboard. Estimates secured from shippers in a hundred principal cities indicate that property valued

at three million four hundred thousand dollars was saved as a direct result of the predictions sent out well in advance of the coming of the severe cold. The utility of these forecasts to the agriculture, the commerce, and the industry of the country is so great that there is hardly a daily paper that does not publish weather forecasts in a prominent place, and there is scarcely a reader who fails to note the predictions.

Twenty-five years ago mariners on our Great Lakes and seaboard depended on their own weather lore to warn them of coming storms. Then, although the number of craft plying our waters was much less than now, every severe storm that swept the Lakes or Atlantic coast left destruction and death in its wake, and for days afterward the dead were cast up by the receding waves, and the shores were lined with wreckage. Happily this is not now the case, for the Weather Bureau is ever watching the changes of atmospheric conditions, and giving to the mariner warning of coming storms. Each observer telegraphs instantly to the Central Office whenever the delicately adjusted instruments at his station show unusual agitation. By this means the inception of many storms is detected when the regular morning and evening reports fail to give notice of their origin.

Some idea of the vast interests floating on the Atlantic coast may be had when it is stated that 5628 trans-Atlantic steamers, with an aggregate of 10,076,148 tons, and 5842 sailing craft, aggregating 2,105,688 tons, entered and left ports on the Atlantic seaboard during a single year ten years ago, and the record is vastly greater now. The value of their cargoes is more than a billion and a half of dollars. Our coastwise traffic is enormous. Fifteen years ago more than seventeen thousand sailing vessels and four thousand steamers entered and left the ports between Maine and Florida. The number has largely increased since. From these facts one can roughly measure the value of the marine property which the Weather Bureau aims to protect by giving warning of approaching storms.

It is the expectation of the meteorologist that some day he will be able to accurately forecast the weather for weeks and months in advance. What a wonderful conservation of human energy would result if it were possible to tell the farmer when the great corn and wheat belts would have abundant rain during the next growing season, or when droughts would parch and wither the vegetation; or to truthfully inform the planter of the South that the coming season would be favorable or un-

favorable for the production of cotton! Effort could be withheld in one part of the country, and greater energy exerted in another.

This extension of forecasting doubtless will be accomplished as the result of further study of solar impulses which disturb the orderly processes of the earth's atmosphere and initiate storms, combined with a comparative study of meteorological data. We may be laying the foundation of a great edifice which shall adorn the civilization of future centuries.

As storms of more or less intensity pass over large portions of our country every few days during the greater part of the year, and as it is seldom that the weather report does not show one or more storms as operating somewhere within our broad domain, it is easy for some charlatan to forecast thunderstorms about a certain time in July, or a cold wave and snow about a certain period in January, and stand a fair chance to accidentally become famous as a prophet. One may select any three equidistant dates in January and forecast high wind, snow, and cold for New York City, and stand a fair chance of having the fraudulent forecast verified in two out of the three cases, provided that you claim a storm coming the day before or the day after one of your dates is the storm that you expected.

From the introduction of the electro-magnetic telegraph in 1844 down to 1869 intermittent advocations were made by many in this country for a national weather service. Finally Doctor Increase A. Lapham, of Milwaukee, scientist and philanthropist, so aroused the property and financial interests of the country with the facts that he presented relative to the destruction of life and property by storms on Lake Michigan that Congress, under provisions of a bill introduced by General Halbert E. Paine, was induced to appropriate money to initiate a service. To General Albert J. Meyer, Chief Signal Officer, U. S. A., was intrusted the duty of inaugurating a tentative weather service by deploying over the country as observers the military signalmen of his command. From this beginning has evolved the present extensive Weather Bureau, which is the largest in the world and more intimately serves the needs of the public than any other.

In 1869 Professor Cleveland Abbe published a weather bulletin at Cincinnati, based upon simultaneous observations secured by telegraph from about thirty stations. He was the first scientific assistant to General Meyer and remained continuously with the service until his death in 1919.

Colonel (afterward Brigadier-General) H. H. C. Dunwoody, U. S. A., served twenty-seven years as an expert forecaster or as the assistant chief of the Weather Bureau. General A. W. Greely, of Arctic fame, the last of the military chiefs, succeeded Brigadier-General William B. Hazen on the death of the latter. Professor Mark W. Harrington was the first chief of the new civil Weather Bureau; he served but four years and was succeeded by Professor Willis L. Moore, who remained chief for eighteen years, serving two years under President Cleveland, who appointed him, and during the entire administrations of McKinley, Roosevelt, and Taft, and was removed by Woodrow Wilson immediately on taking office. Professor Moore claims the honor of having been the first presidential appointee to incur the displeasure and receive the public condemnation of Woodrow Wilson. The present chief is Professor Charles F. Marvin, who for many years served as an assistant to Professor Moore.

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